



National Aeronautics and Space Administration

UAS Integration into the NAS: iHITL: DAA Display Evaluation Preliminary Results

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Overview

- Goals:
 1. Leverage the lessons learned from PT4 to continue the evaluation of candidate Sense and Avoid (SAA) with respect to pilot performance of the self-separation function
 - What are the individual contributions of the various PT4 advanced display features to pilots' response times and ability to maintain well clear?
 2. Introduce non-cooperative intruders to examine effect of different sensor ranges on pilots ability to maintain well clear
- Rationale
 - PT4 compared a 'Basic' display configuration to a suite of 'Advanced' features
 - iHitL design will allow us to measure any differences between specific display features and determine the implications of their presence or absence in the GCS
 - Non-cooperative traffic are a major consideration in the development of SAA systems
 - The presence of non-cooperative aircraft provides a more realistic environment
 - Limited surveillance range and field of regard may have significant impact on pilot performance and behavior



Experimental Design



- One-Way Repeated Measures Factorial: Display Information Level (4 Level; Within Subjects)
 - D1: Advanced Display with Information Only
 - D2: Advanced Display with Information + Vector Planner
 - D3: Advanced Display with Information + Auto Resolutions
 - D4: Advanced Display with Information + Vector Planner + Auto Resolutions
 - Roughly same as 'Advanced' suite in PT4
- Embedded Variable
 - Track Type (manipulated within each scenario; not counterbalanced)
 1. Cooperative Traffic (ADS-B-equipped)
 - Range = 80nm & +/- 5000ft
 2. Non-Cooperative Traffic
 - Range = 6nm
 - Azimuth = +/- 110deg (from nose)
 - Elevation = +/- 20deg (from horizontal)

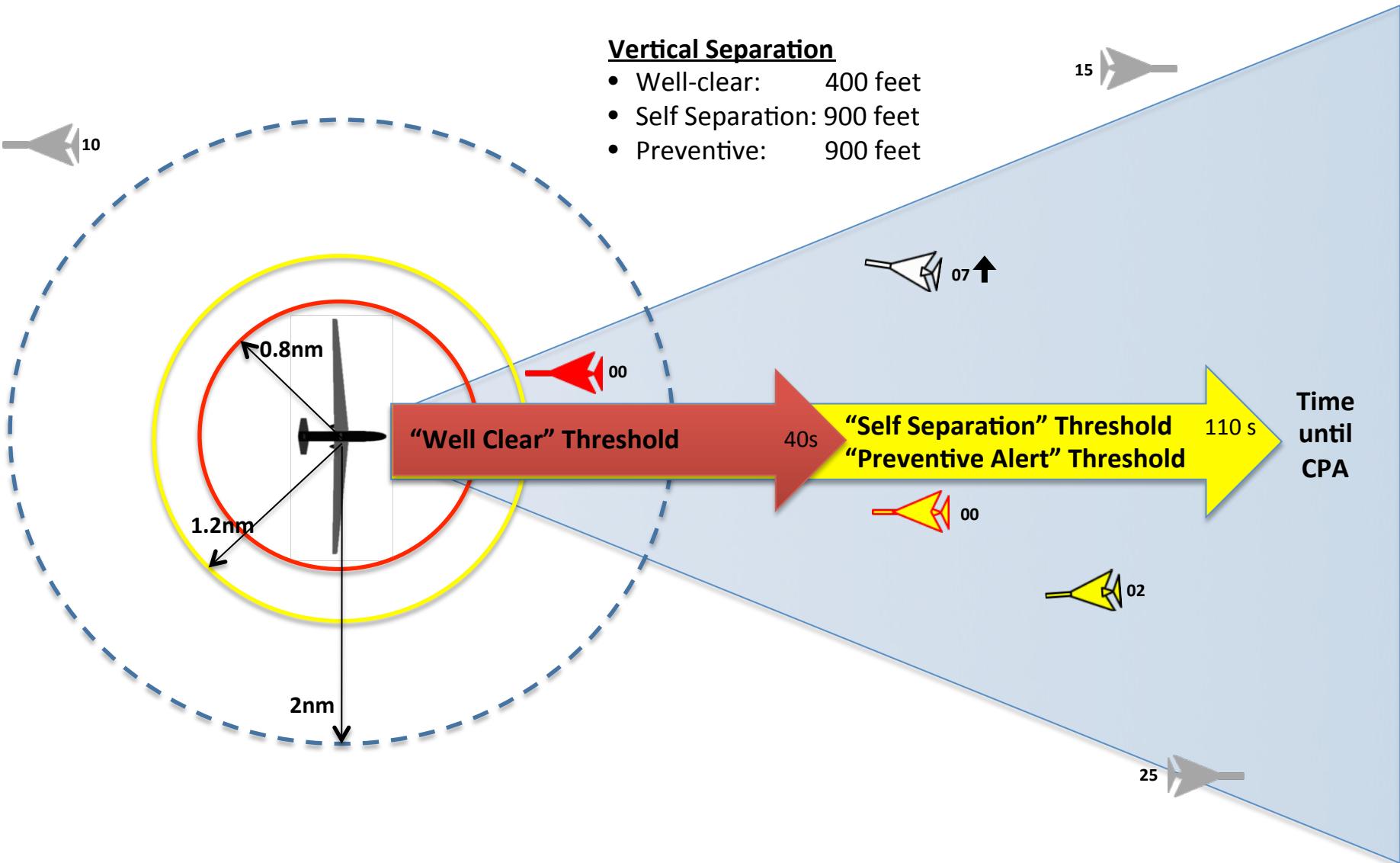


Alerting Criteria



Vertical Separation

- Well-clear: 400 feet
- Self Separation: 900 feet
- Preventive: 900 feet



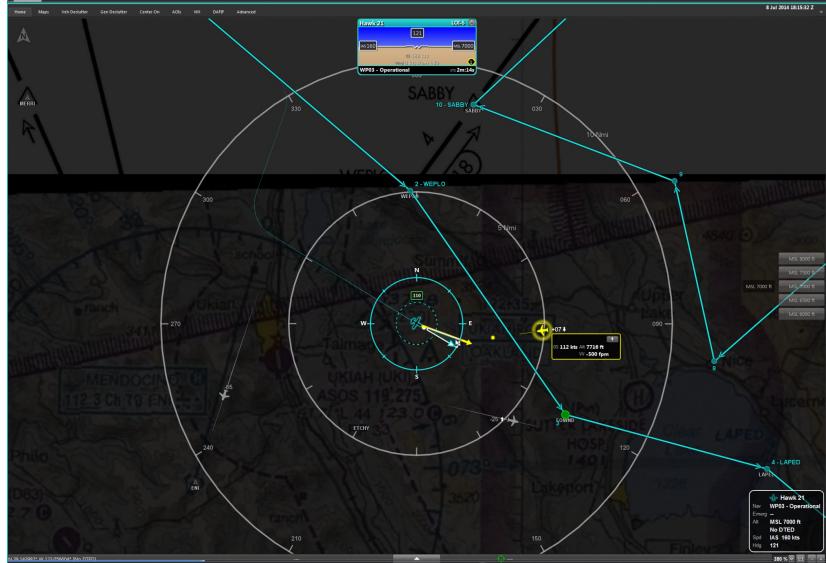


Display Conditions

D1



D2



D3



D4





D1 Encounter



The screenshot displays the Vigilant Spirit Control Station software interface. The main window shows a map of a coastal region with various locations marked, including '4 - LAPED', '5 - WUSHU', and '6 - DALON'. A circular flight plan is centered over '5 - WUSHU'. The software includes several windows: 'Hawk 21' and 'Hawk 21' (repeated), 'Steer Hawk 21', 'Flight Plan', and a message box. The 'Flight Plan' window indicates that the vehicle does not support loiter mode. The bottom right corner shows a summary of the flight parameters for 'Hawk 21'.

Hawk 21 (Top Left):

- Alt: 179 ft
- MSL: 9001 ft
- IAS: 160 kts
- Spd: 160 kts
- Hdg: 129 deg
- Altitude: 29.93 inulg

Steer Hawk 21 (Top Right):

- WP: WP05 - WUSHU - Op
- Alt: MSL 9000 ft
- IAS: 160 kts
- Hdg: 129 deg
- Altitude: 29.93 inulg

Flight Plan (Bottom Right):

This vehicle does not support loiter mode.

Hawk 21 Summary (Bottom Right):

- WP05 - WUSHU - Operational
- Energy: —
- Alt: MSL 9001 ft
- No DTEC
- IAS: 160 kts
- Hdg: 129

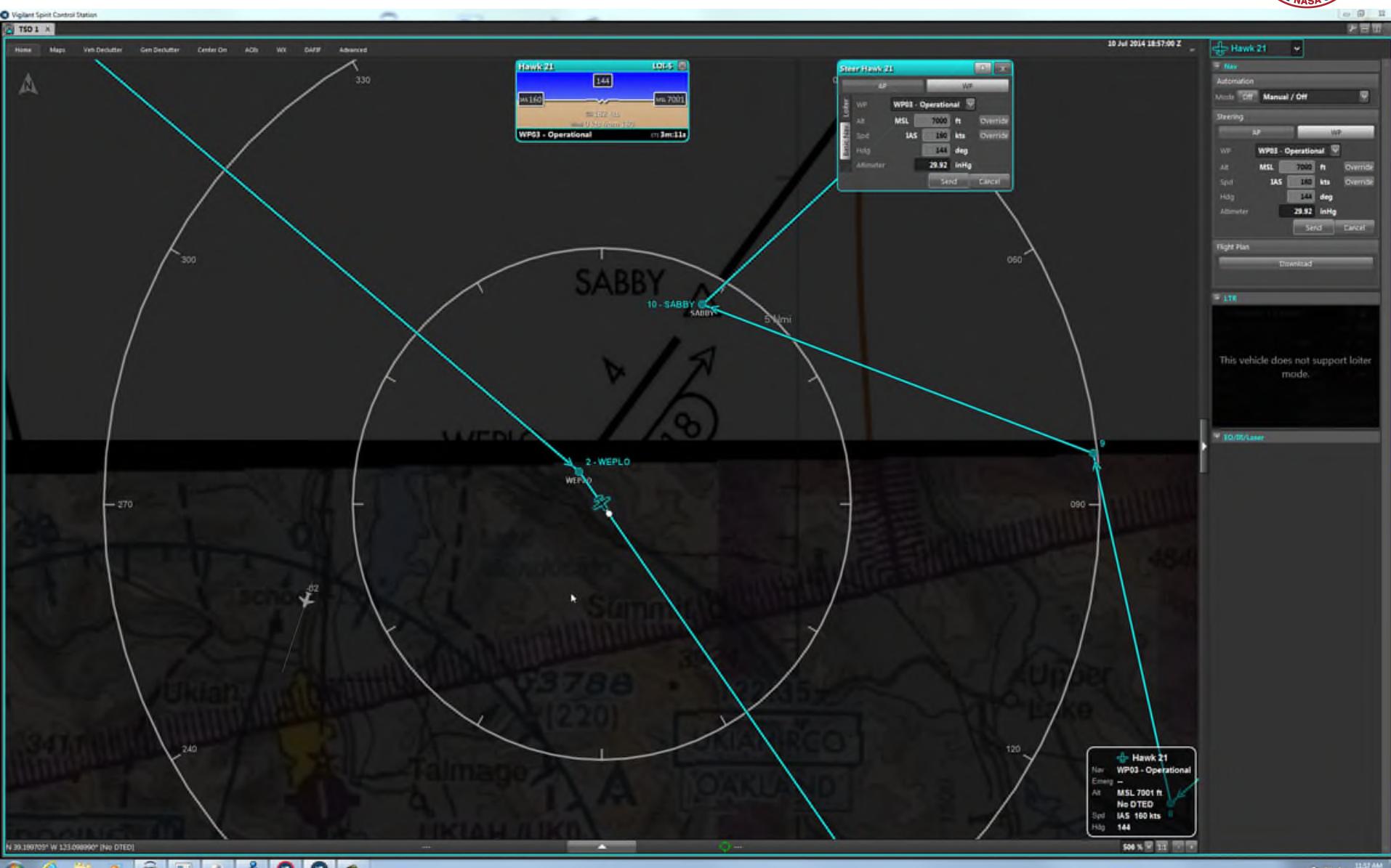


D2 Encounter



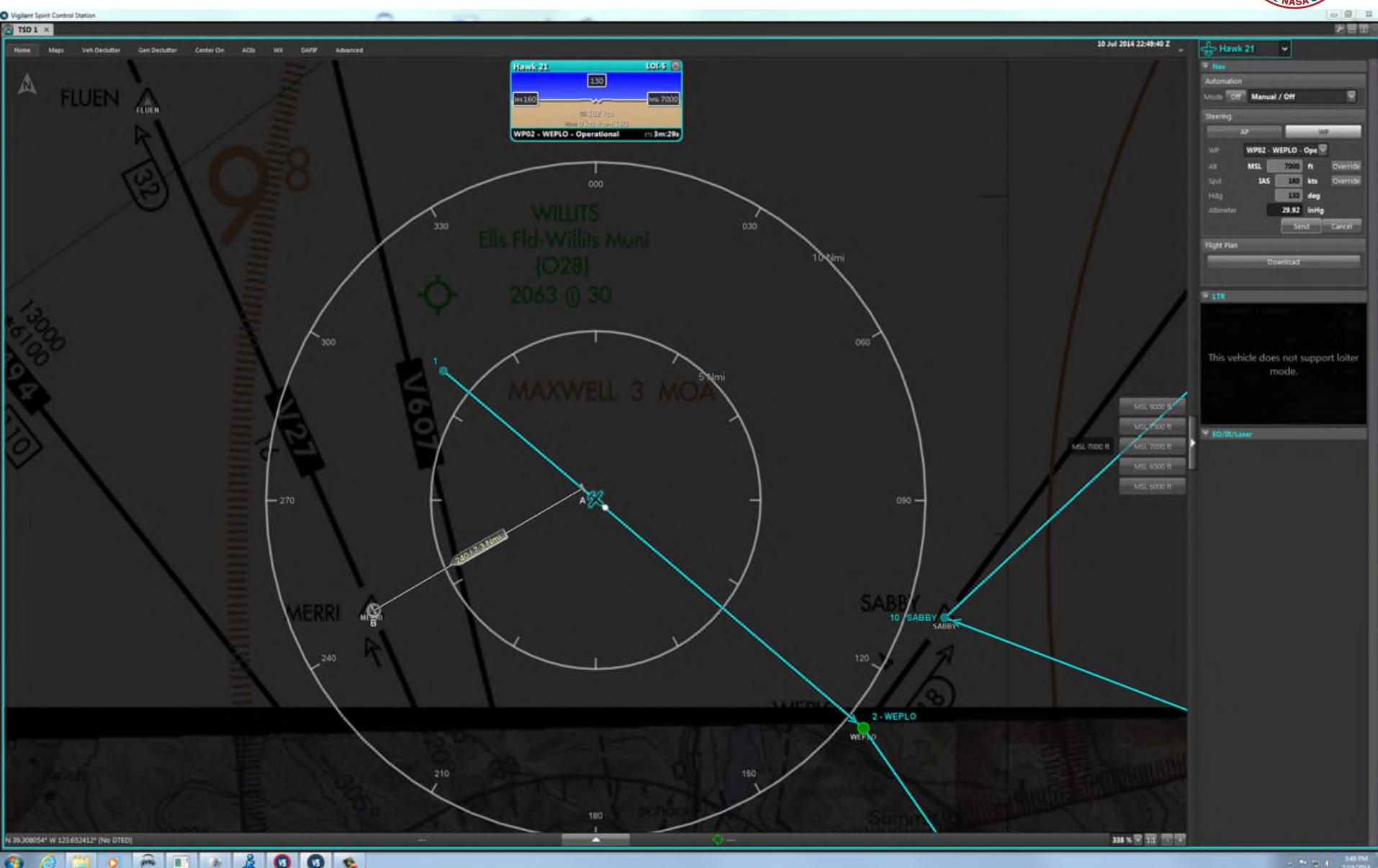


D3 Encounter





D4 Encounter





Participants

- Participants:
 - 4 MQ-1 Predator/MQ-9 Reaper Pilots (avg. 46 years old)
 - All received Undergraduate Pilot Training
 - 5 RQ-4 Global Hawk Pilots (avg. 33 years old)
 - 3 received Undergraduate Pilot Training
 - 1 received RQ-4 Basic Training (AF Specialty Code 18X)
 - 1 received cross training
 - All 9 pilots had military UAS experience
 - Military Combat & Non-Combat Experience = avg. 1182 hours
 - Civilian Airspace = avg. 153 hours
 - 5 pilots had less than 50 hours of experience flying in civilian airspace
 - 1 retired Air Traffic Controller with experience in Oakland Center airspace (confederate)



Procedure



- UAS Scenario (38min)
 - UAS: Predator B
 - Airspace: ZOA 40/41
 - Class A & E with mixed IFR/VFR traffic
 - Manned traffic modeled using real traffic data
- Primary Tasks:
 1. Fly HAWK21 along pre-filed path (Fire Line)
 - Only responsible for navigating the aircraft
 - Requires interaction with the GCS and coordination ATC
 2. Comply with ATC clearances and traffic display alerts to maintain safety of flight
- Secondary tasks:
 - ‘Chat’ directed
 - “Mission” Radio Frequency changes
 - Radial and Distance check
 - Nominal information requests (e.g., fuel level remaining)
 - System Alerts
 - Generator Failure (checklist)
 - Tanker Header Overpressure (checklist)
 - Annunciator checks



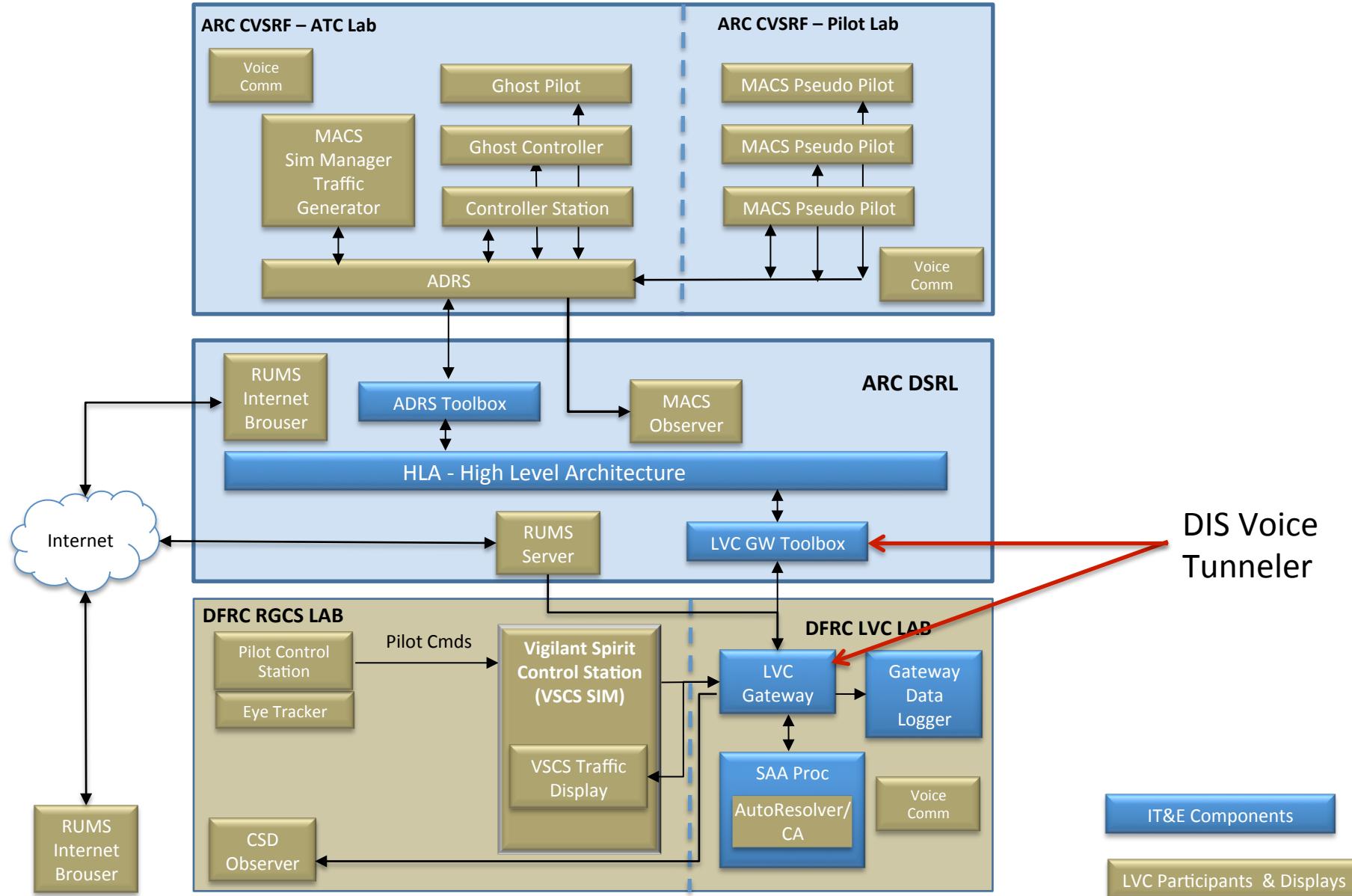


Research Ground Control Station





Simulation Architecture





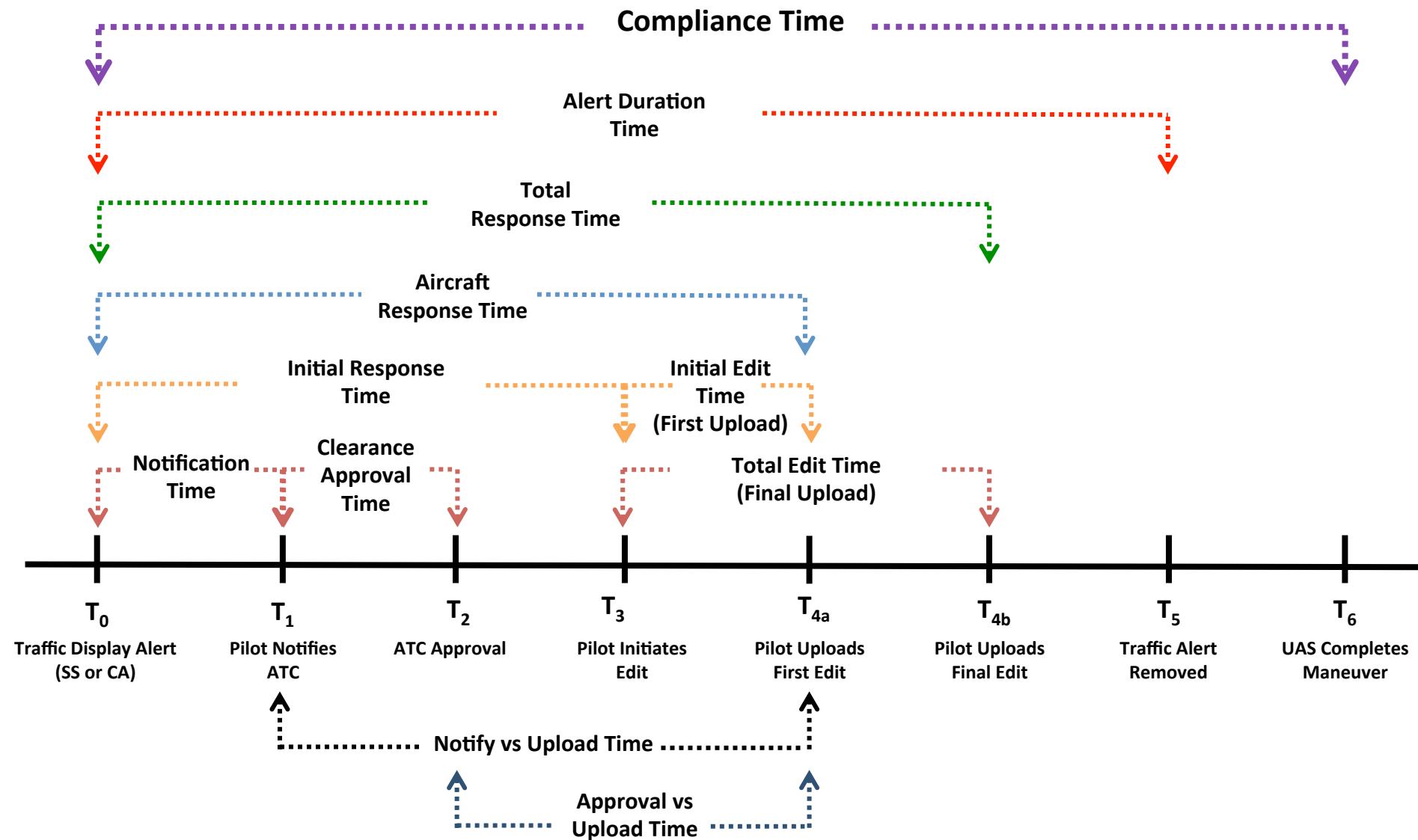
Initial Research Question



- What was the effect of the DAA guidance tools on pilots' performance in response to self separation alerts?
 - Same measured response metrics as those captured in PT4
- Measured Response data were analyzed utilizing 5 separate One-Way Analyses of Variance (ANOVAs)
 - I. Independent Variable: Display
 - 1) D1: Advanced Display with Information Only
 - 2) D2: Advanced Display with Information + Vector Planner
 - 3) D3: Advanced Display with Information + Auto Resolutions
 - 4) D4: Advanced Display with Information + Vector Planner + Auto Resolutions
 - II. Analyses for: Alert Type and Intruder Type
 - 1) All self separation (SS) alerts
 - 2) Predictive SS alerts (yellow with red outline; collapsed across Intruder Type)
 - 3) Non-Predictive SS alerts (yellow; collapsed across Intruder Type)
 - 4) Cooperative SS alerts (collapsed across Alert Type)
 - 5) Non-Cooperative SS alerts (collapsed across Alert Type)

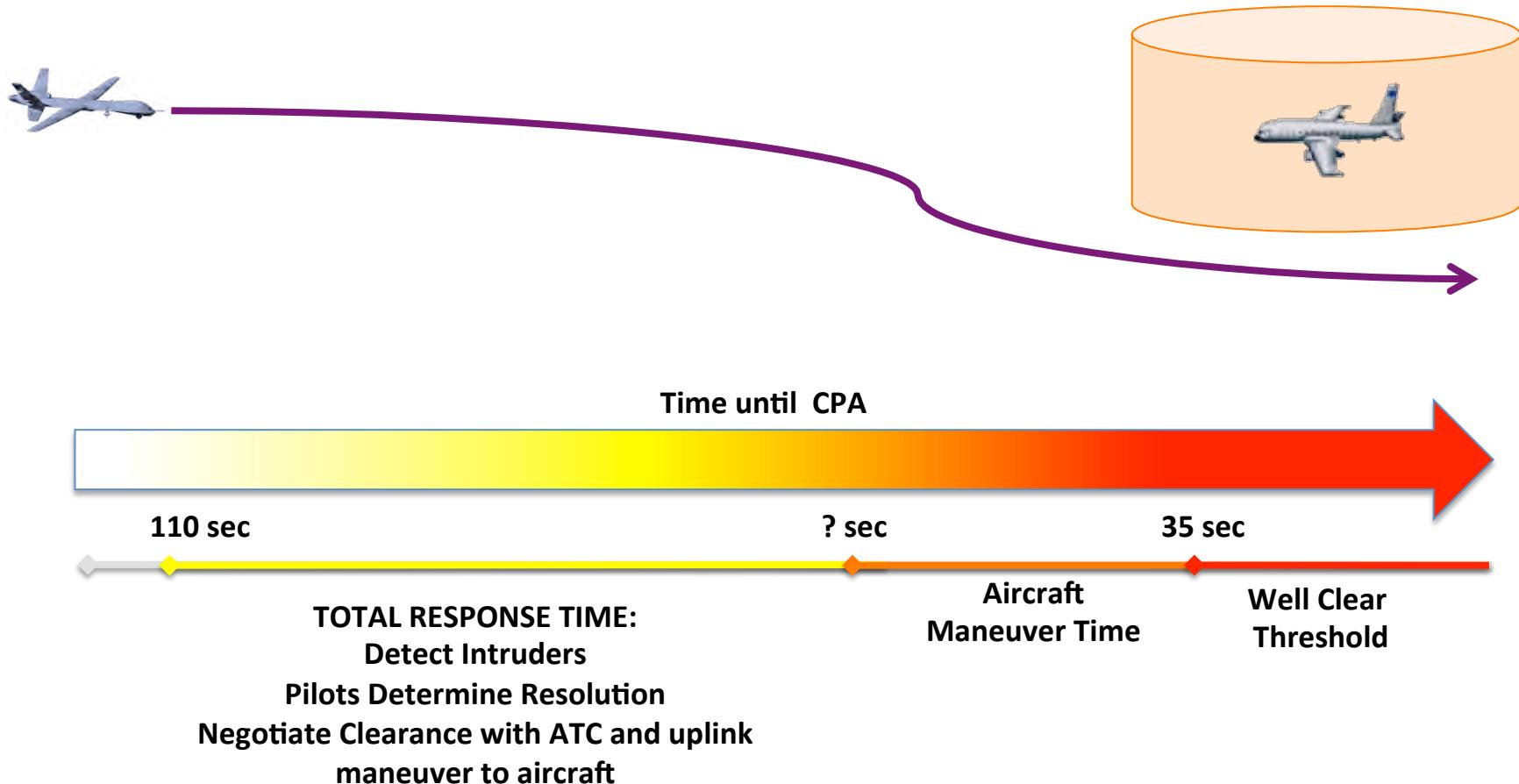


Stages of Pilot DAA Task





Self-Separation Timeline





Encounter Statistics



- Total Number of Encounters:
 - Alert Type:
 - 134 Predictive SS Alerts
 - 115 Non-Predictive SS Alerts
 - Intruder Type:
 - 92 Cooperative
 - 157 Non-Cooperative
- Pilots responded to a total of 196 Self Separation Alerts
 - Alert Type:
 - 122 Predictive SS Alerts (91% of total)
 - 74 Non-Predictive SS Alerts (64% of total)
 - Intruder Type:
 - 61 Cooperative (66% of total)
 - 135 Non-Cooperative (86% of total)
 - Alert Type X Intruder Type:
 - 25 Cooperative/Predictive
 - 36 Cooperative/Non-Predictive
 - 97 Non-Cooperative/Predictive
 - 38 Non-Cooperative/Non-Predictive



Data Slides Organization



- Slides organized by metric
 - Analysis of Variance (ANOVA) results for All SS Alerts
 - Was there an effect of Display on the dependent variable?
 - ANOVA by Alert Type
 - ANOVA by Intruder Type
 - Means of the Alert/Intruder Type by Display
 - Means of Display by Alert/Intruder Type
 - Comparison of display means for PT4 and iHITL



iHTL Results



Summary of Results

	PT4 Grand Mean	iHTL Grand Mean	All SS	Predictive	Non-Predictive	Cooperative	Non-Cooperative
Notification Time	29.07s	14.03s	X	X	X	X	X
Clearance Approval Time	5.08s	5.54s	X	X	X	X	X
ATC Notification vs Upload Time	3.51s	0.18s	p = .075	X	p < .05	p = -.55	X
ATC Approval vs Upload Time	-1.52s	-6.46s	p = .092	X	p < .05	p = .070	X
Initial Response Time	19.32s	8.52s	X	X	X	X	X
Initial Edit Time	11.77s	6.29s	p < .01	p < .05	p < .05	p < .01	p = .056
Total Edit Time	17.65s	9.83s	X	p < .05	X	X	p = .064
Aircraft Response Time	32.19s	14.54s	p = .069	p = .059	p < .05	p < .01	X
Total Response Time	37.87s	18.08s	X	p = .056	X	X	X
Alert Duration Time	48.61s	33.58s	X	X	X	X	X
Compliance Time	71.43s	37.53s	p < .05	p < .05	X	X	X

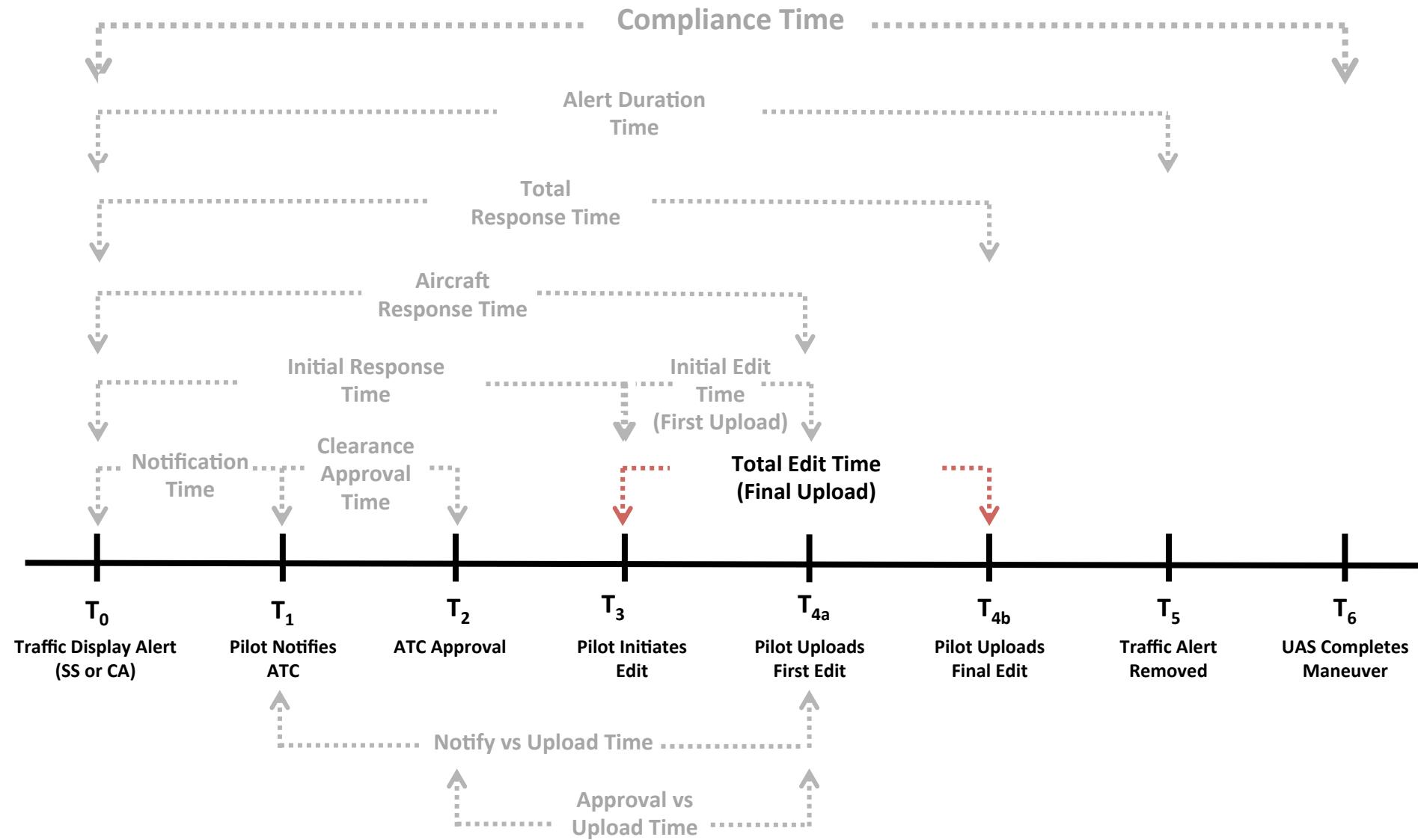
Only 6 significant differences between display conditions



Some Results:
Total Edit Time
Total Response Time

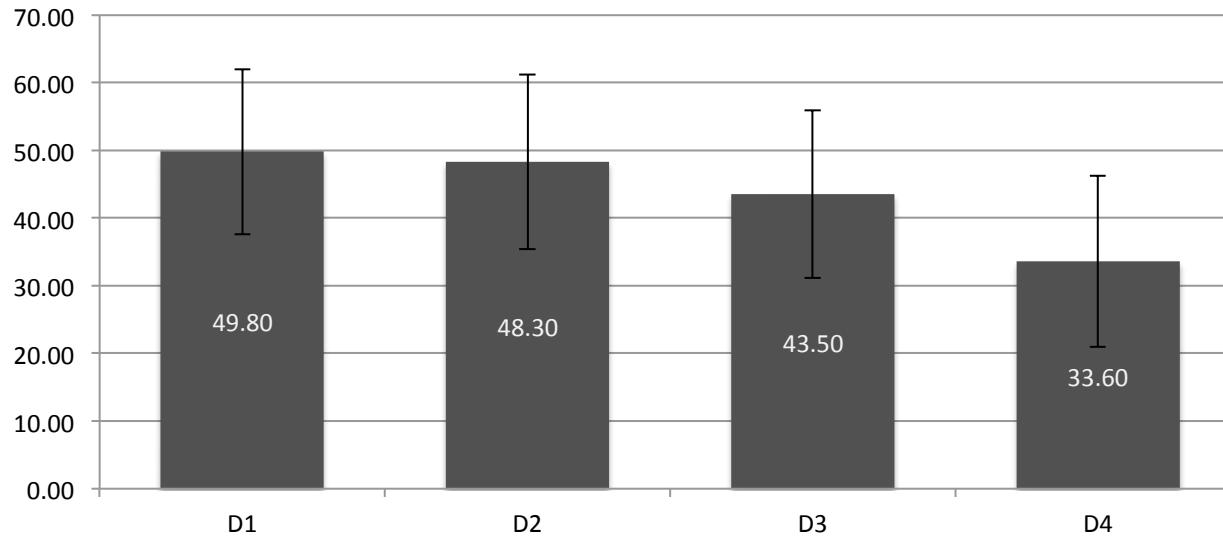


Stages of Pilot DAA Task





Total Edit Time

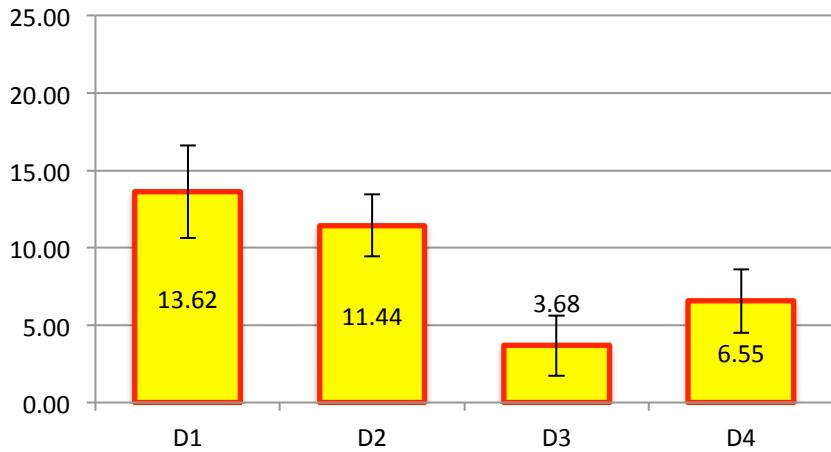


- There was a not significant effect of Display on Total Edit Time for all SS alerts, $p > .05$
- Pilots took an average of **9.83 seconds** to complete their final edit in response to SS alerts



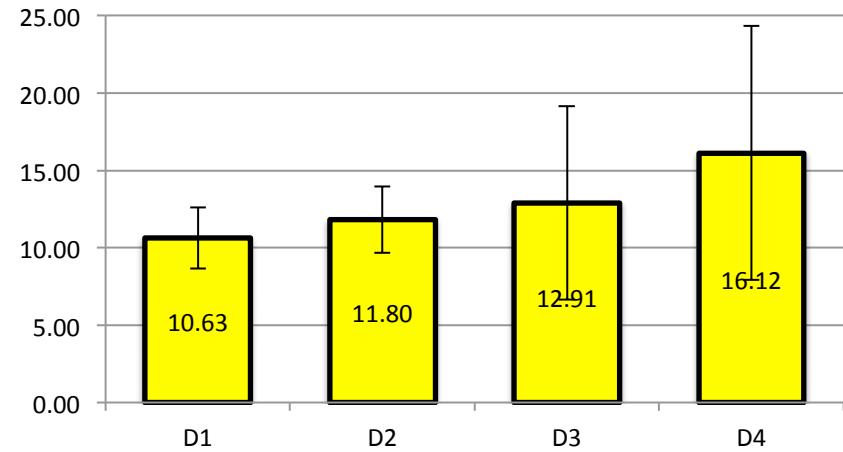
Total Edit Time

Predictive SS Alerts



- There was a significant effect of Display on Total Edit Time for Predictive alerts, $p < .05$
 - D3 was significantly faster than D2, but no different than the other two displays
- Pilots took an average of **8.83 seconds** to complete their final edit in response to Predictive SS alerts

Non-Predictive SS Alerts

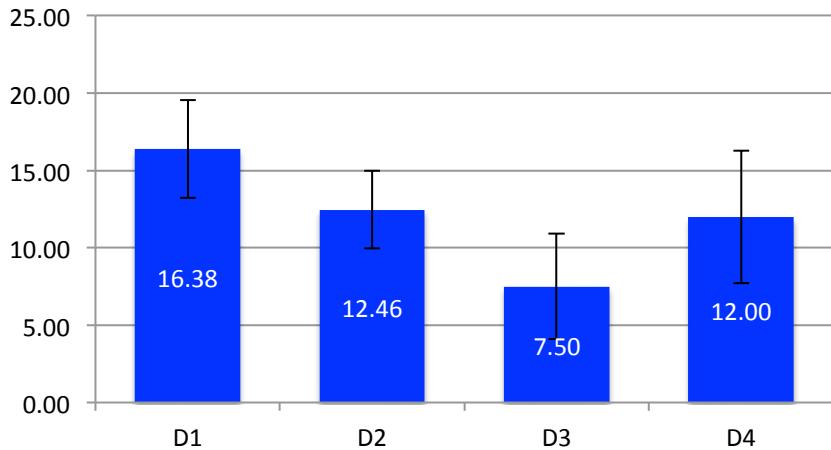


- There was no significant main effect of Display on Total Edit Time for Non-Predictive alerts, $p > .05$
- Pilots took an average of **12.862 seconds** to complete their final edit in response to Non-Predictive SS alerts



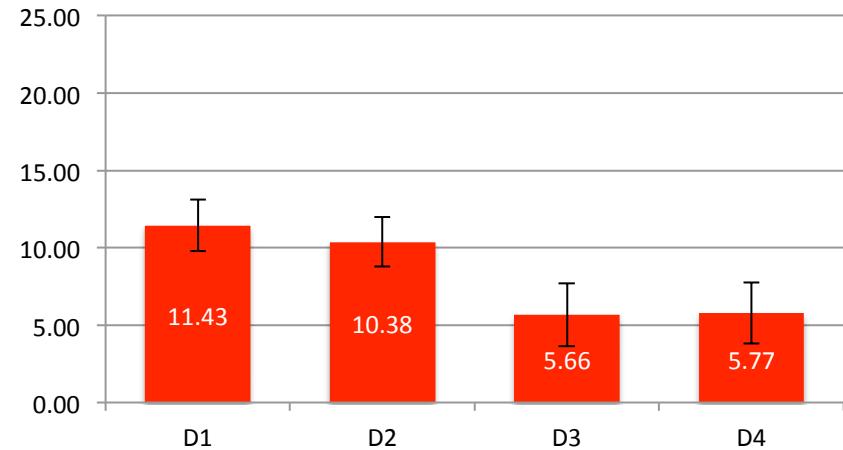
Total Edit Time

Cooperative SS Alerts



- There was no significant effect of Display on Total Edit Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **12.08 seconds** to complete their final edit in response to Cooperative SS alerts

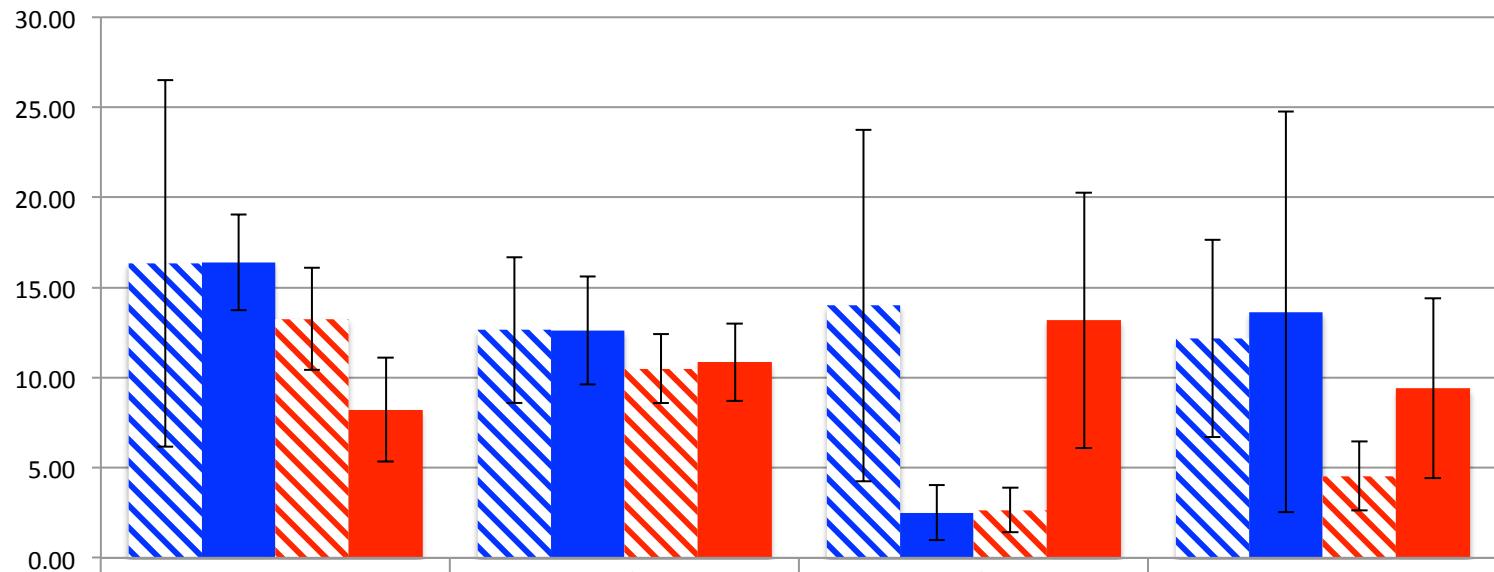
Non-Cooperative SS Alerts



- There was a near significant effect of Display on Total Edit Time for Non-Cooperative SS alerts, $p = .064$
- Pilots took an average of **8.31 seconds** to complete their final edit in response to Non-Cooperative alerts



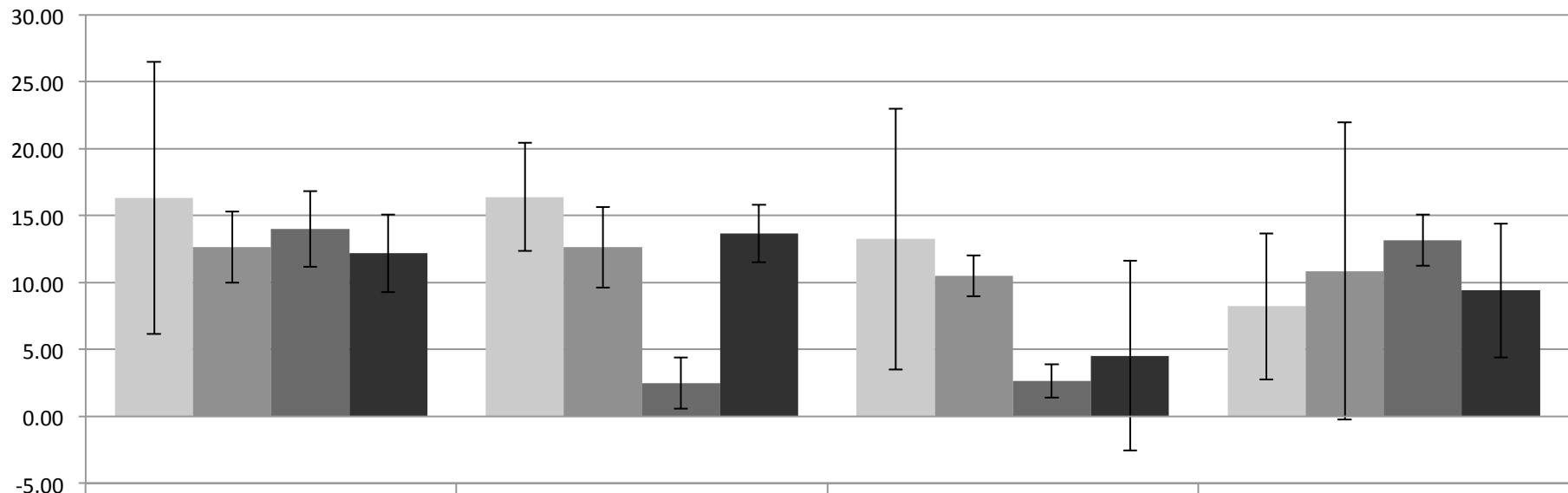
Total Edit Time



Cooperative/Predictive	16.33	12.64	14.00	12.17
Cooperative/Non-Predictive	16.40	12.63	2.50	13.64
Non-Cooperative/Predictive	13.26	10.50	2.64	4.54
Non-Cooperative/Non-Predictive	8.21	10.86	13.17	9.40



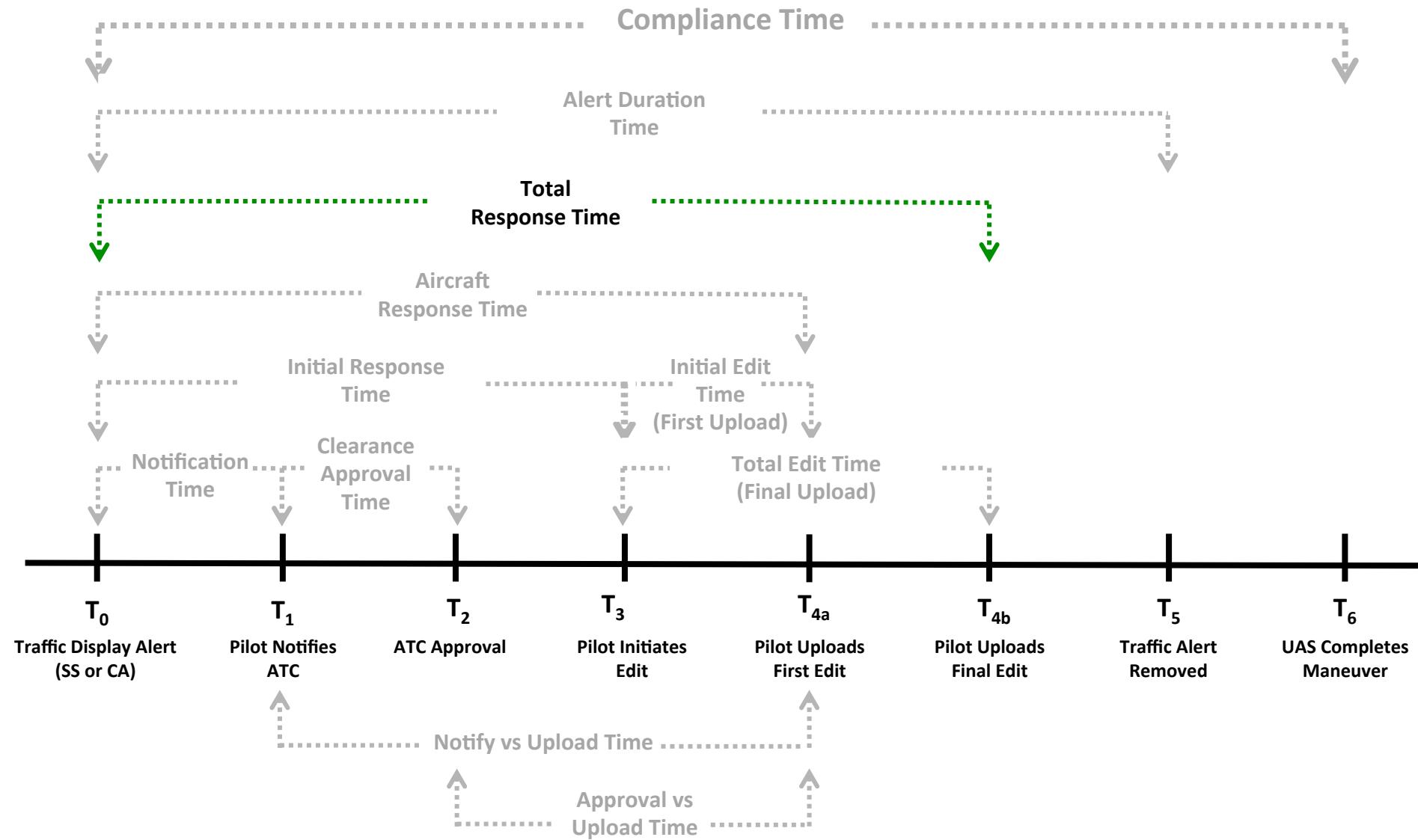
Total Edit Time



	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	16.33	16.40	13.26	8.21
D2	12.64	12.63	10.50	10.86
D3	14.00	2.50	2.64	13.17
D4	12.17	13.64	4.54	9.40

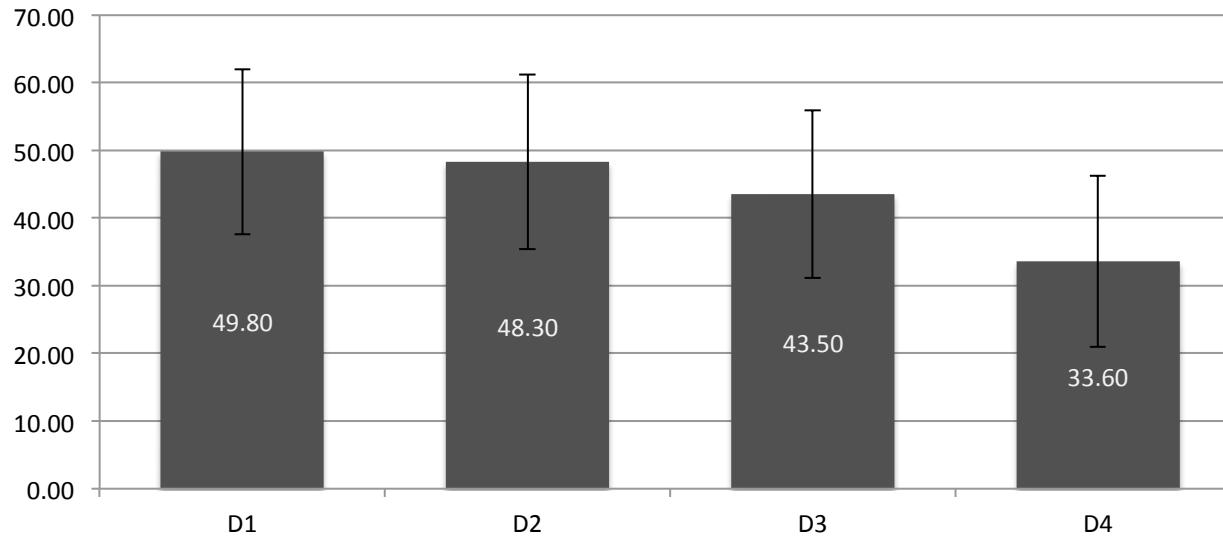


Stages of Pilot DAA Task





Total Response Time

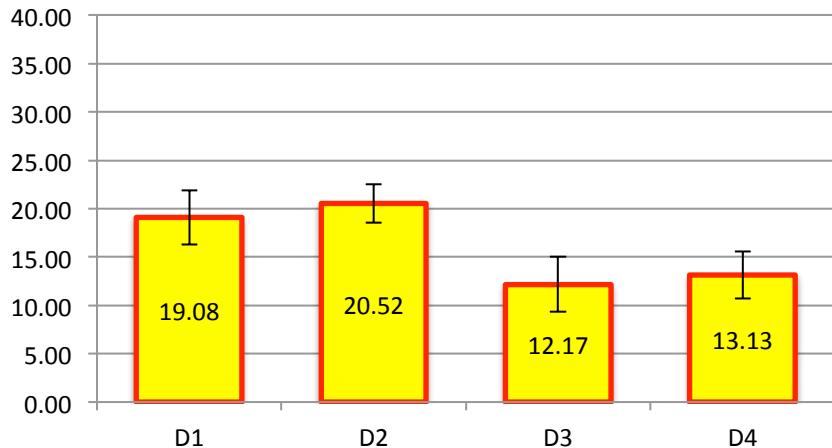


- There was not a significant effect of Information on Total Response Time for all SS alerts, $p > .05$
- Pilots took an average of **18.08 seconds** to complete their final edit in response to SS alerts (from first alert appearance)



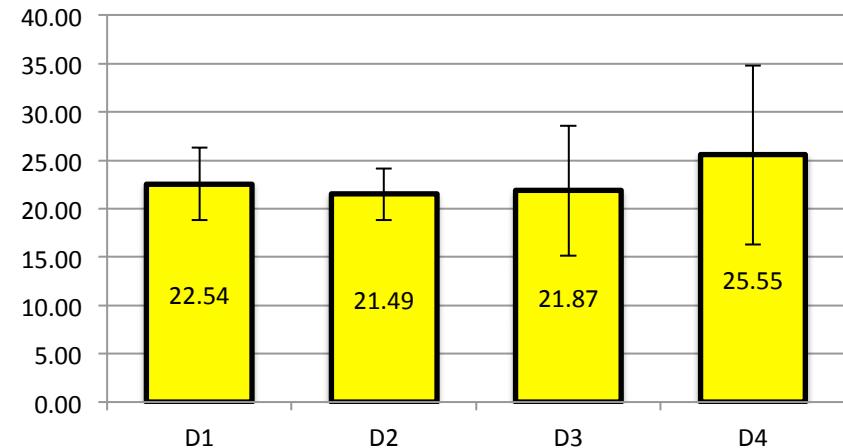
Total Response Time

Predictive SS Alerts



- There was a near significant effect of Display on Total Response Time for Predictive SS alerts, $p = .056$
- Pilots took an average of **16.22 seconds** to complete their final edit in response to Predictive SS alerts (from first alert appearance)

Non-Predictive SS Alerts

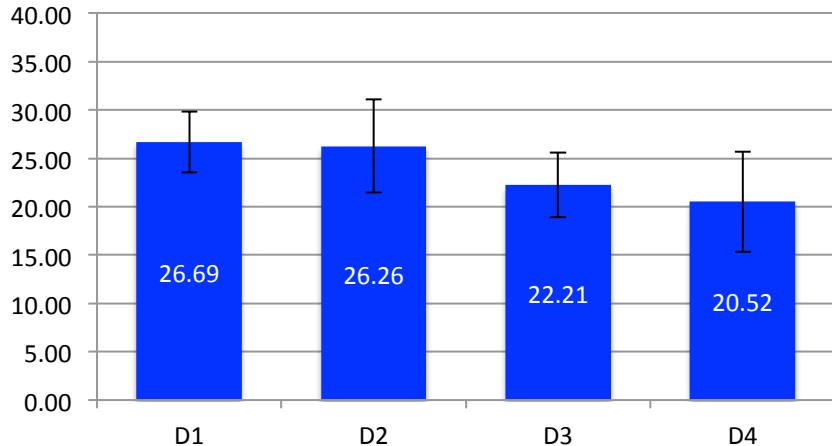


- There was no significant effect of Display on Total Response Time, $p > .05$
- Pilots took an average of **22.86 seconds** to complete their final edit in response to Non-Predictive SS alerts (from first alert appearance)



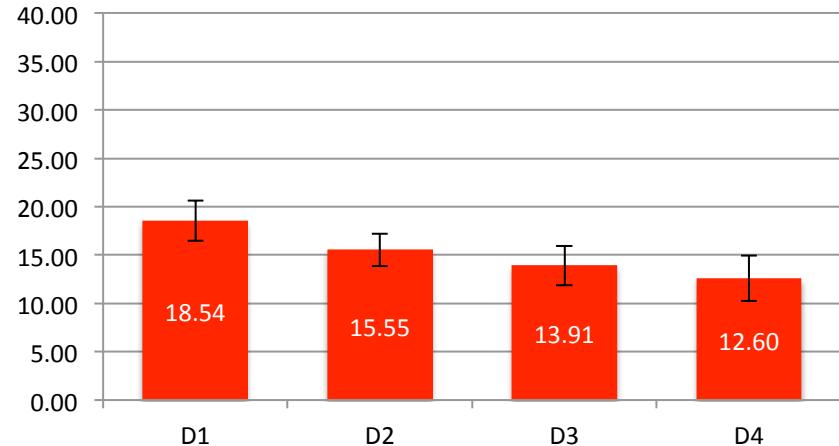
Total Response Time

Cooperative SS Alerts



- There was no significant effect of Information on Aircraft Response Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **23.92 seconds** to complete their final edit in response to Cooperative SS alerts (from first alert appearance)

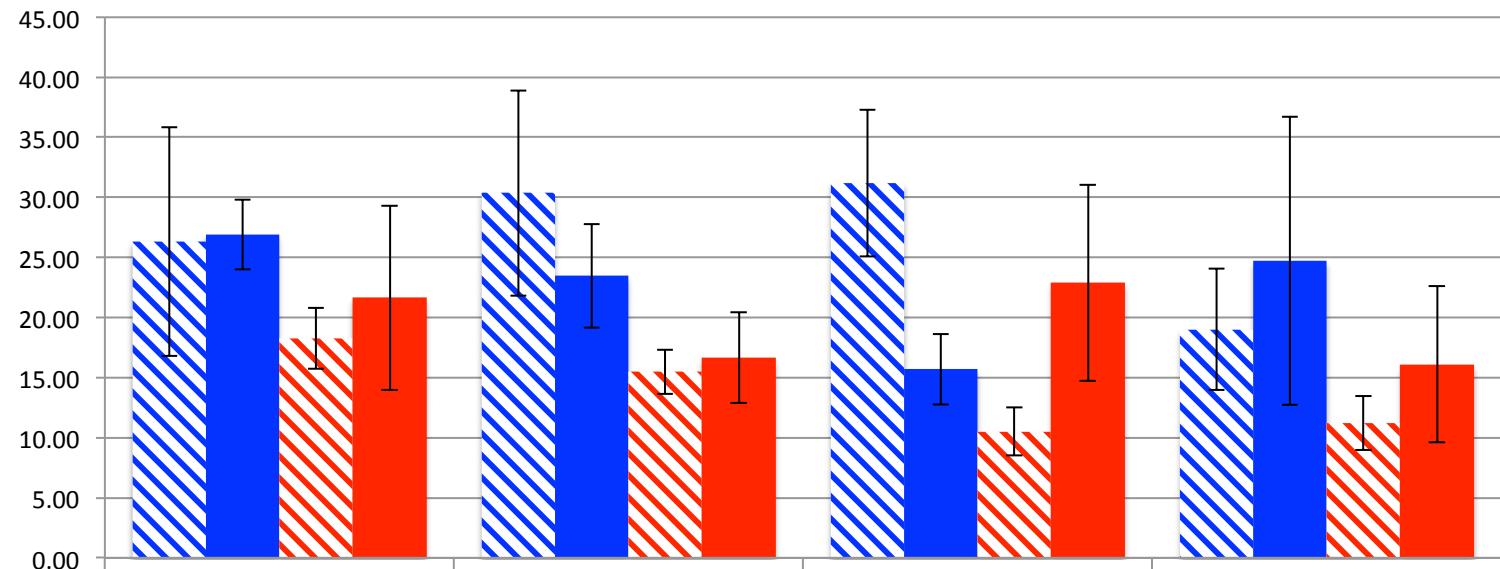
Non-Cooperative SS Alerts



- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average of **15.15 seconds** to complete their final edit in response to Non-Cooperative SS alerts (from first alert appearance)



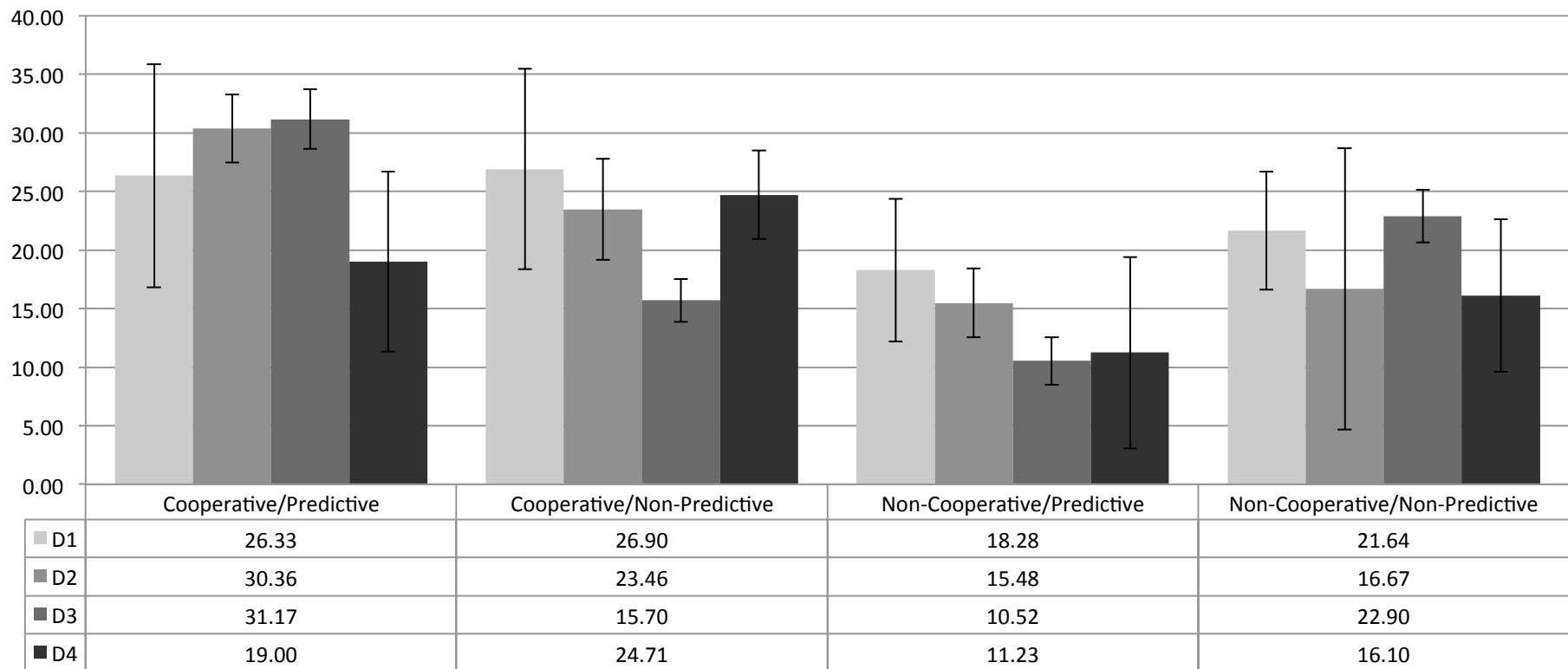
Total Response Time



Cooperative/Predictive	26.33
Cooperative/Non-Predictive	26.90
Non-Cooperative/Predictive	18.28
Non-Cooperative/Non-Predictive	21.64



Total Response Time





iHITL Results Summary



- Few Meaningful Significant Results
 - Except for one, all for edit times where D3, and sometimes D4, are significantly faster
 - Does not translate to significant difference in total response time
 - No more than 8.5s difference between fastest and slowest times from Non-Cooperative/Predictive
- Some overall Trends:
 - Predictive alerts tended to have faster response times than Non-Predictive alerts
 - Non-Cooperative alerts tended to have faster response times than Cooperative alerts
 - Except for Edit Times, appears to be less variability across Intruder/Alert (especially Non-Cooperative/Predictive) type than Display type



iHTL Results Summary



- Initial Response Time:
 - Non-Cooperative on average 5 seconds faster than Cooperative
 - Intruder/alert type appears more predictive of response time with low variability between D1 – D4
 - Non-Cooperative/Predictive fastest overall
- Initial Edit Time:
 - D3 consistently significantly fastest
 - D1 consistently significantly slowest
 - Lower variability for D3 and D2, higher variability for D1 and D4 across Intruder type
- Total Edit Time:
 - D3 significantly faster than D2 for Predictive SS alerts only (about 8 seconds faster)
 - Non-Cooperative on average 4 seconds faster than Cooperative
 - Least variability in D2 across Intruder/Alert Type
- Aircraft Response Time
 - D4 significantly faster than D1 and D2 (10-20 seconds)
 - Lowest and least variability in response times for Non-Cooperative/Predictive
 - Least variability in D4
- Total Response Time
 - No significant results
 - Predictive on average 5.5 seconds faster than Non-Predictive
 - Non-Cooperative on average 9 seconds faster than cooperative



iHITL and PT4 Results



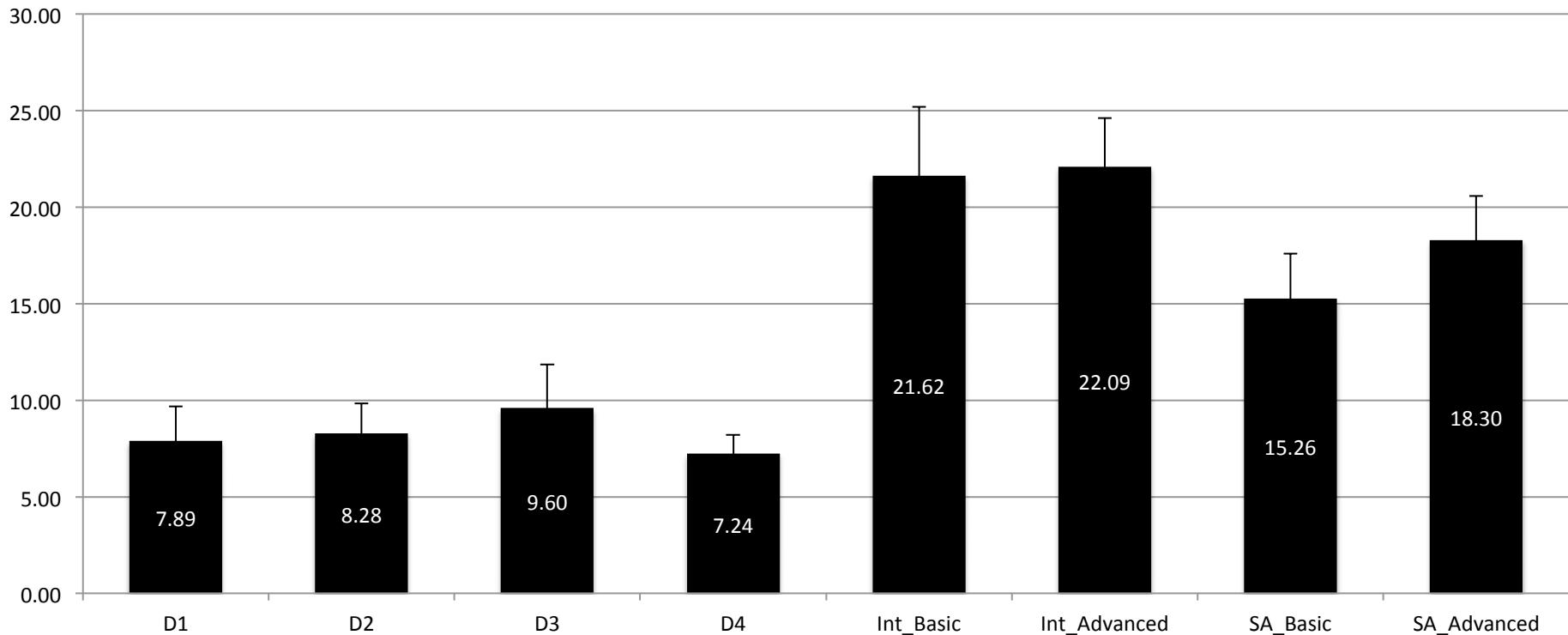
- iHITL Response Times faster than PT4 Response Times
- Closest comparisons:
 - PT4 Basic_Integrated (Basic) vs. iHITL D1
 - D1 **added** information: predictive alert level, well clear ring, intruder CPA location
 - PT4 Advanced_Integrated (Advanced) vs. iHITL D4
 - D4 **removed** information: vertical situation display, ownship CPA, time to CPA
- Initial Response Time, about 11 seconds faster overall (19.32s vs. 8.52s)
- Total Edit Time, about 8 seconds faster overall (17.65s vs. 9.82s)
- Total Response Time, about 8 seconds faster overall (37.87s vs. 18.08s)

Measure	PT4 Basic	iHITL D1	PT4 Advanced	iHITL D4
Initial Response Time	22	8	22	7
Total Edit Time	23	13	10	9
Total Response Time	45	21	32	16



Initial Response Time

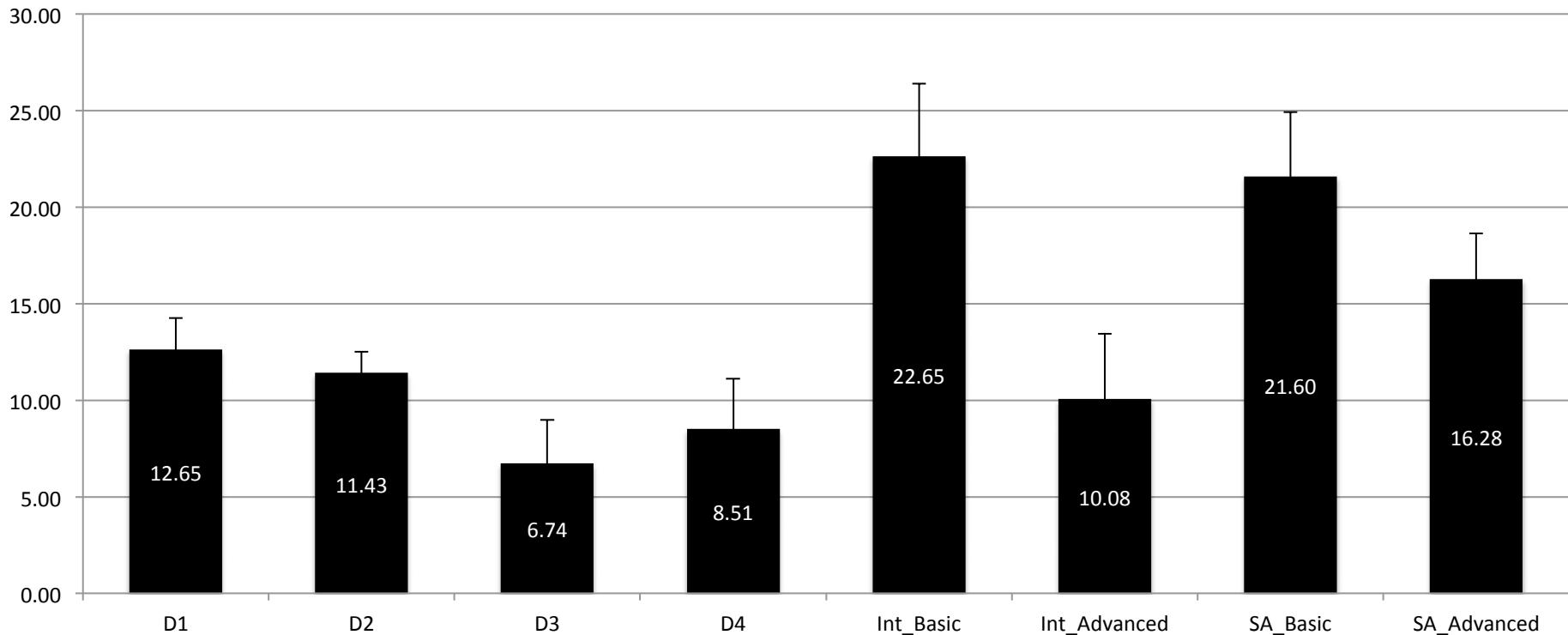
IHTL and PT4 Display Comparison





Total Edit Time

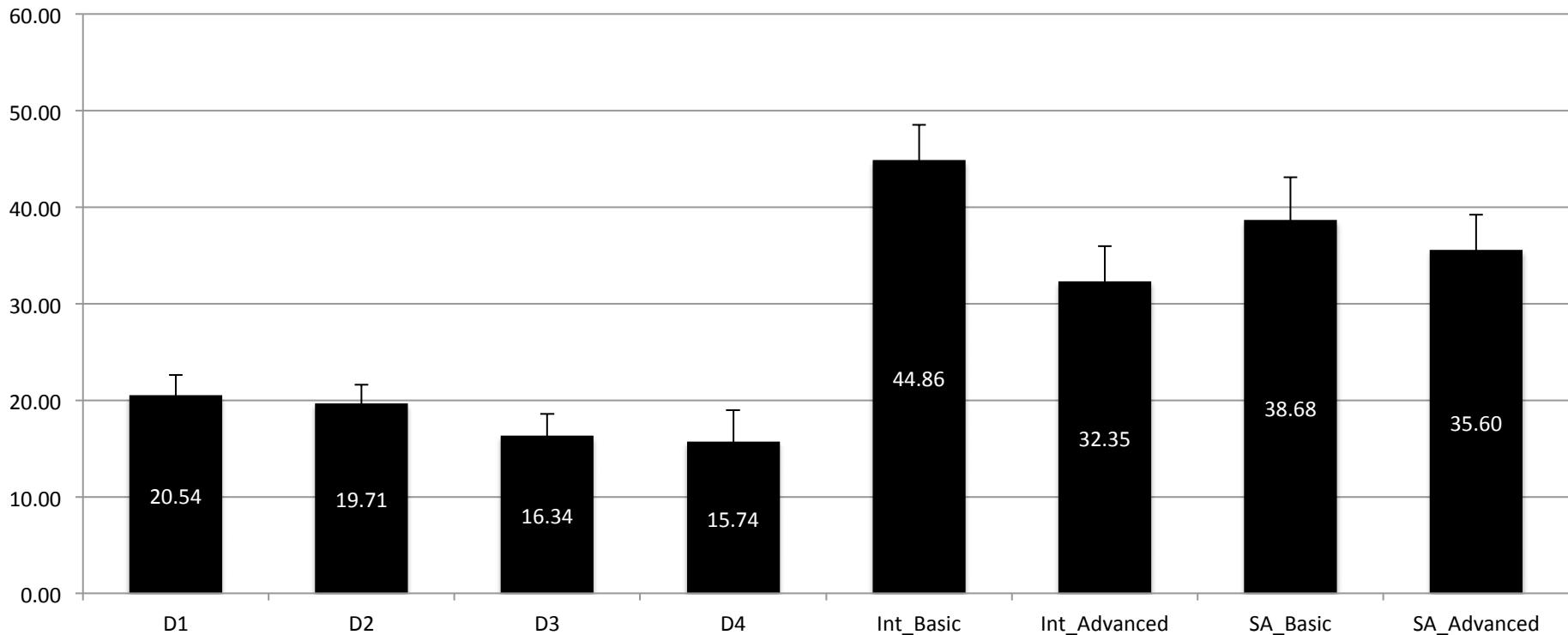
IHTML and PT4 Display Comparison





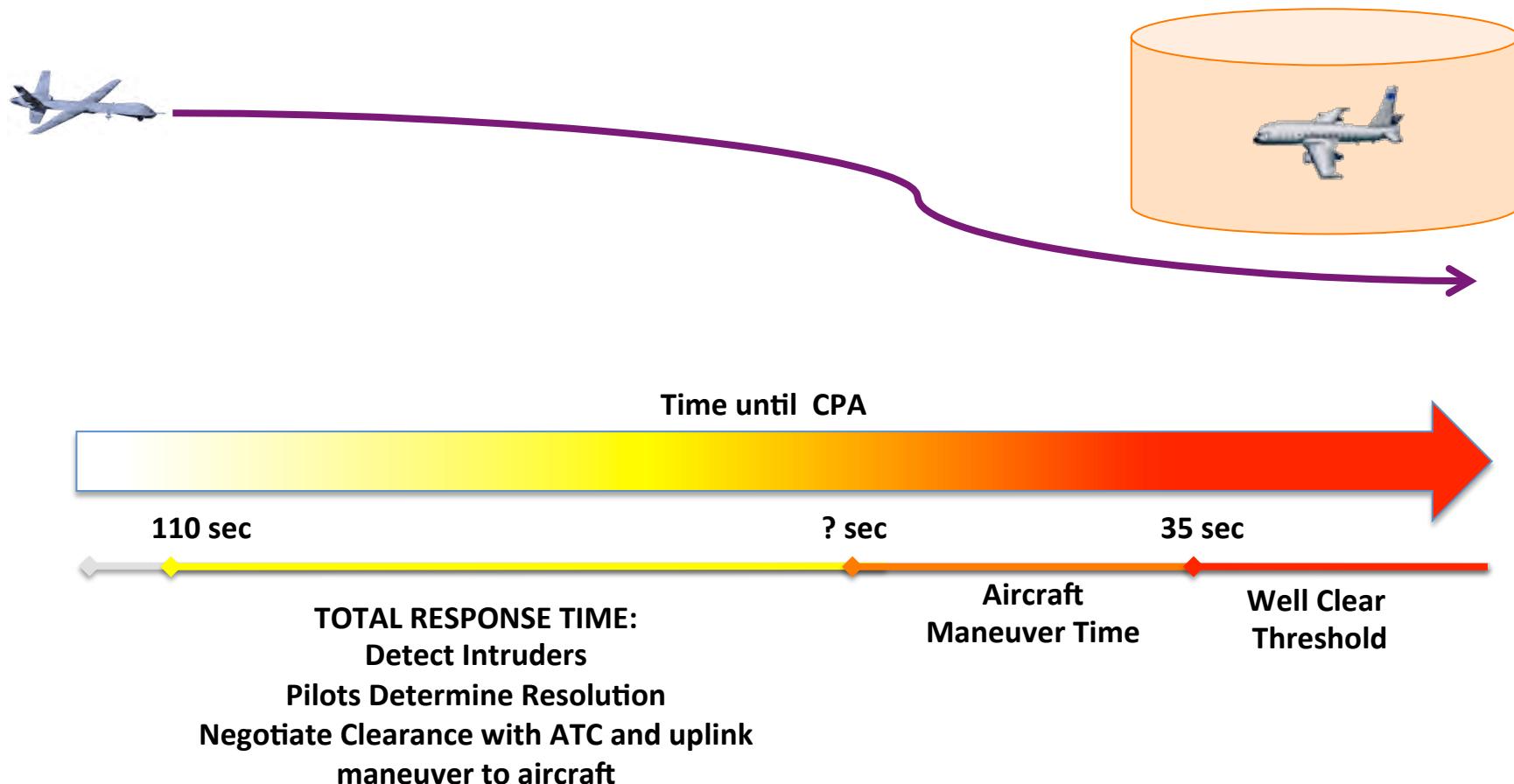
Total Response Time

IHTL and PT4 Display Comparison



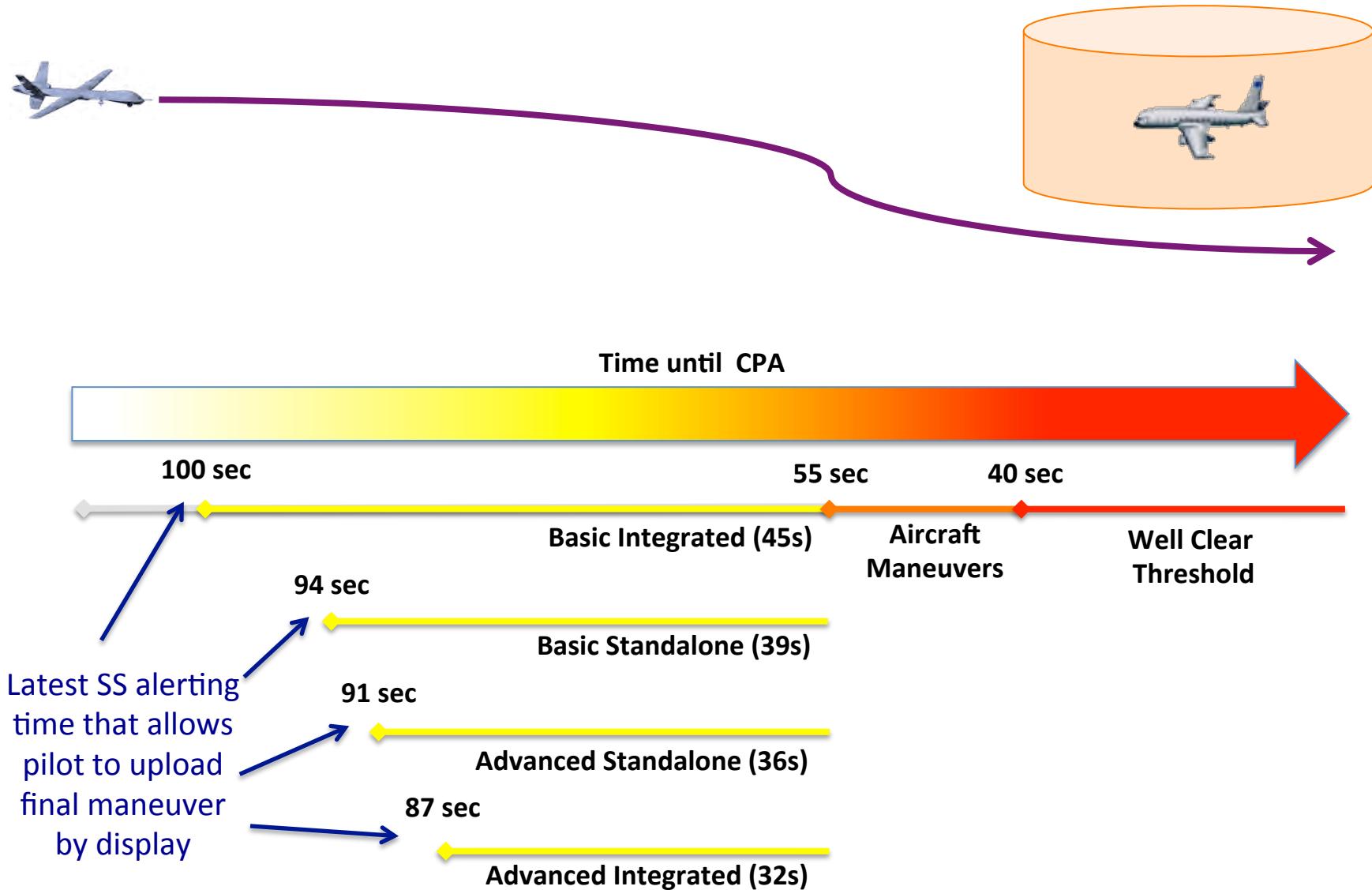


Self-Separation Timeline



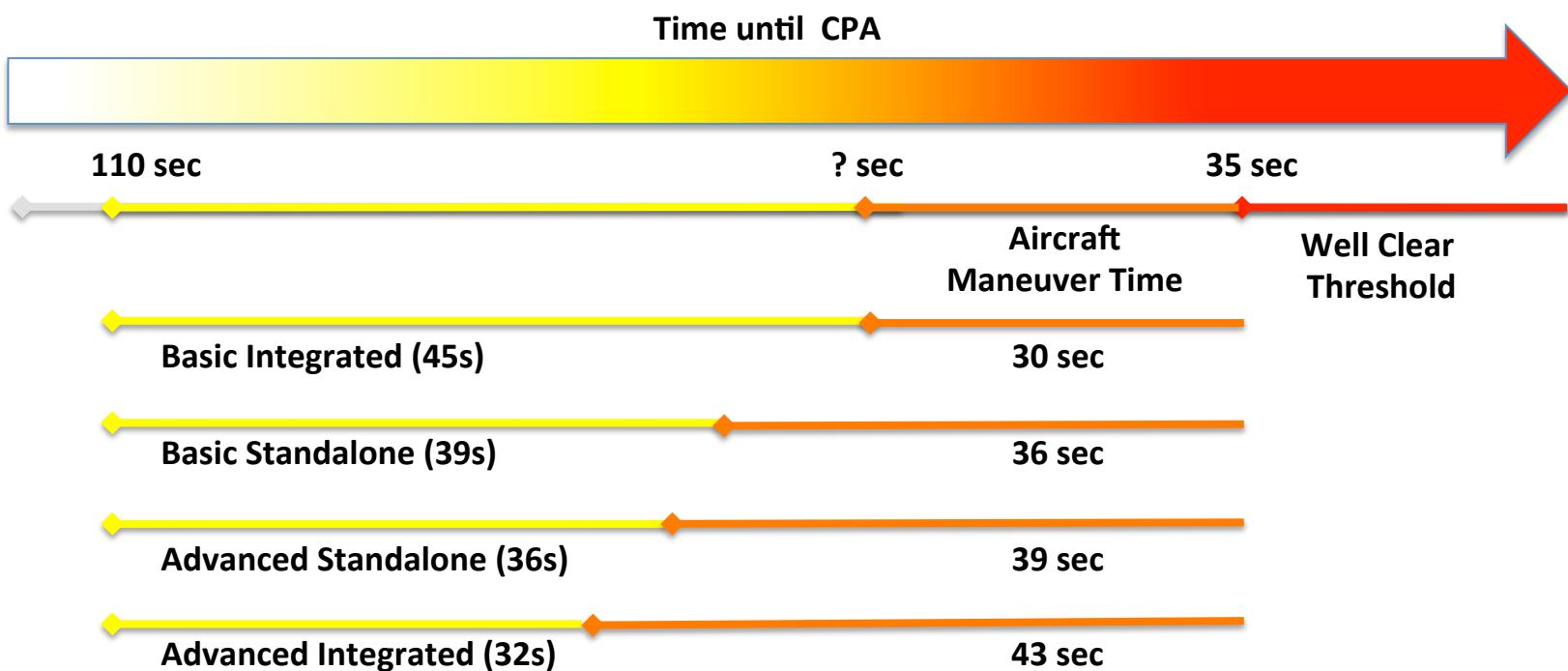


Self-Separation Timeline



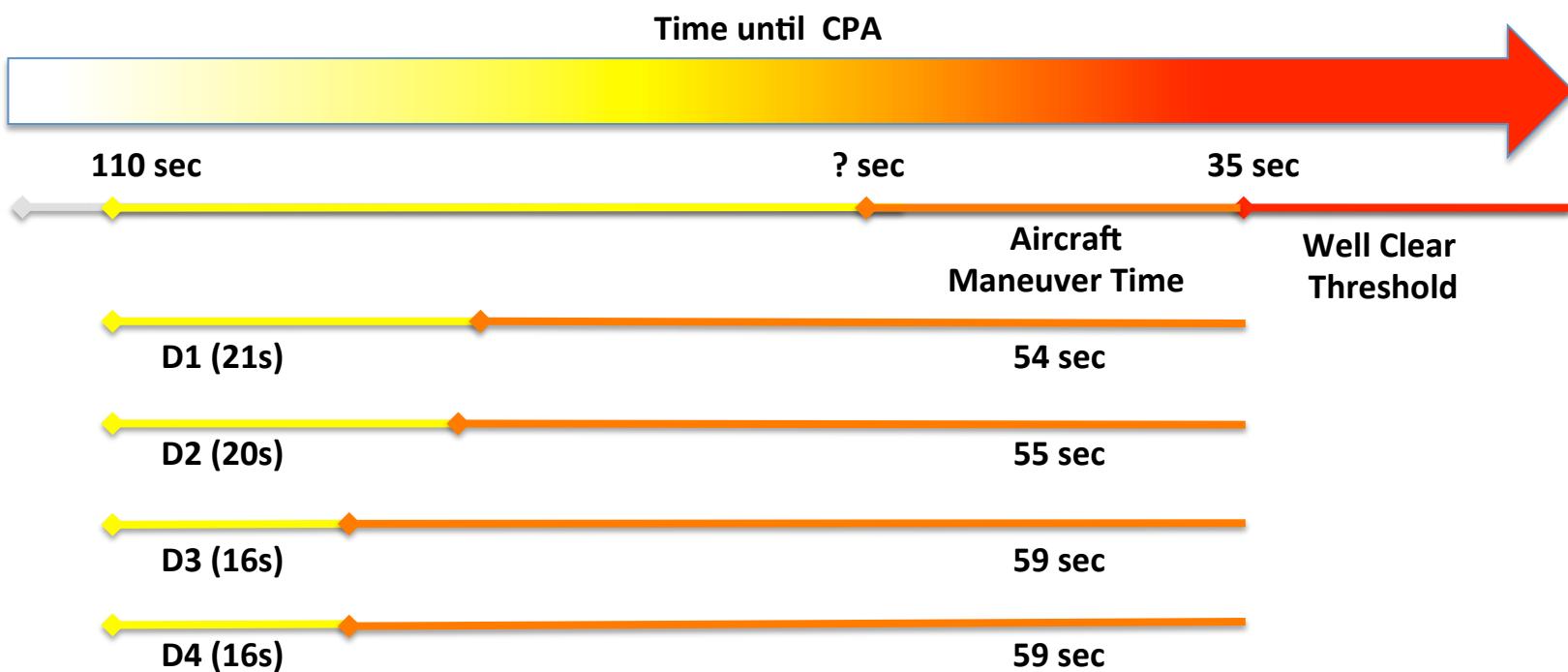


Self-Separation Timeline





Self-Separation Timeline





DAA Task

- What does the DAA Task add to pilot response times?
 - A number of subtasks:
 - Detect
 - Determine
 - Execute
- Can compare to pilot response times when responding to ATC clearances in same navigation mode (AutoPilot; full mission simulation)
 - Assumption that ATC response is near immediate
 - Auto resolution conditions (D3 and D4) actually *reduce* edit times

Measure	FM AP Mean	iHITL Grand Mean	Difference
Initial RT	1.23s	8.25s	+7.02s
Initial Edit Time	9.11s	6.29s	-2.82s
Total Edit Time	9.25s	9.83s	+0.58s
Aircraft RT	10.43s	14.54s	+4.11s



HSI Follow on Research



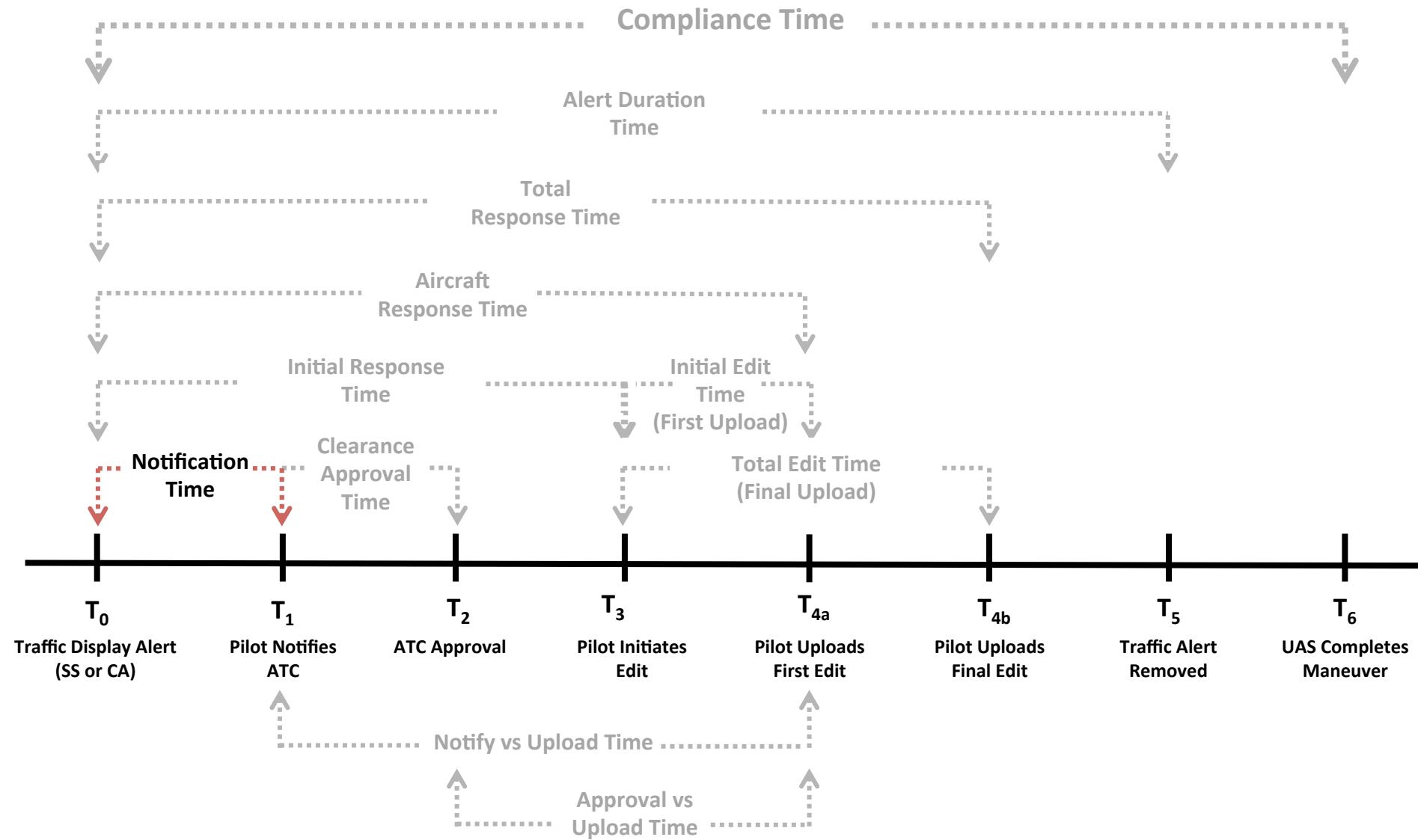
- Part Task Simulation 5
 - Goal: Continue examining DAA display concepts
 - Revisit a minimum information display condition – PT4 Basic with predictive alert level
 - Evaluate suggestive and informative displays
 - Evaluate effect of nominal uncertainty on displays and pilot performance
 - [Data Collection March 2014](#)



All Results Slides

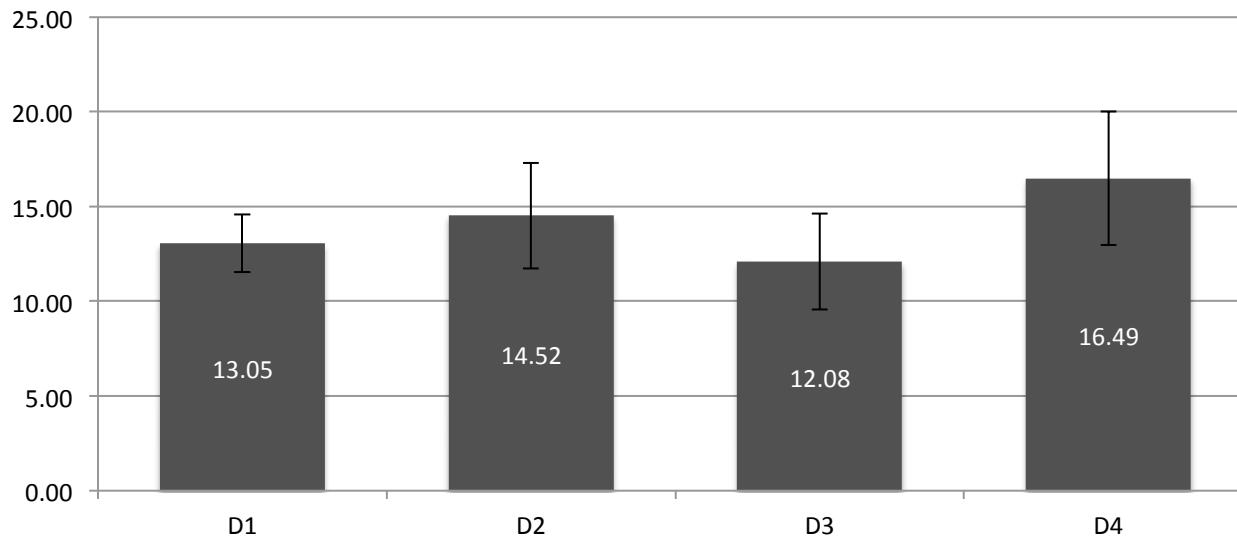


Stages of Pilot DAA Task





ATC Notification Time



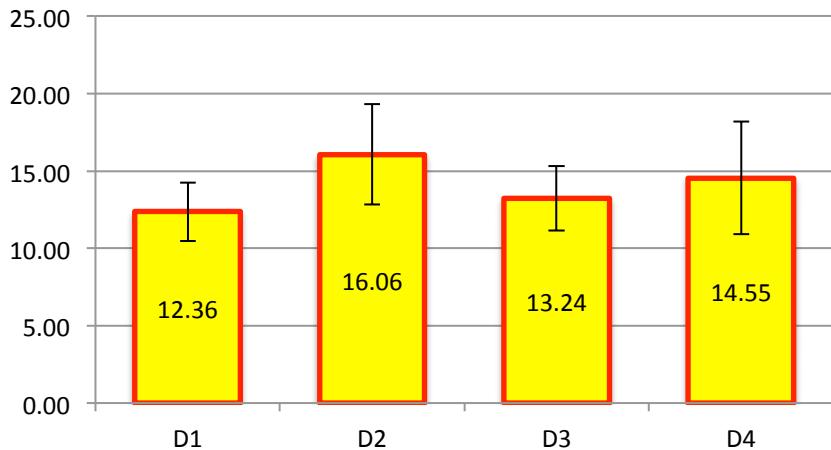
- There was not a significant main effect of Display on ATC Notification Time for all SS alerts, $p > .05$
- Pilots took an average of **14.03 seconds** to notify ATC of a maneuver in response to a SS alert



ATC Notification Time

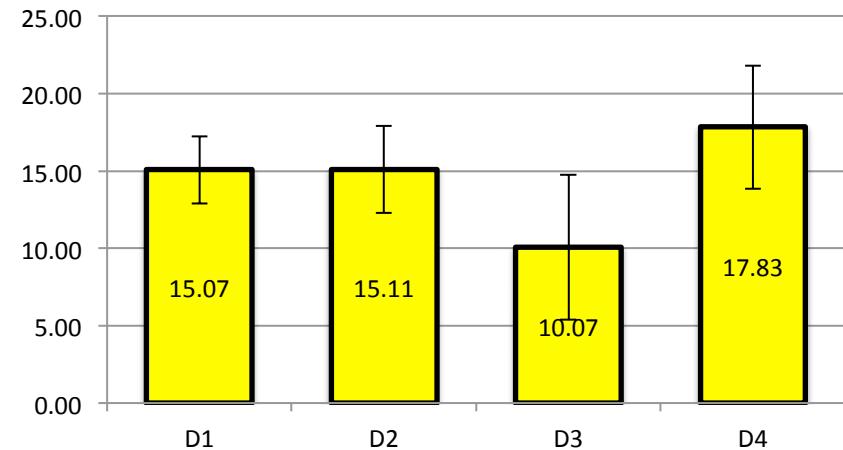


Predictive SS Alerts



- There was no significant effect of Display on ATC Notification Time for Predictive SS alerts, $p > .05$
- Pilots took an average of **14.05 seconds** to notify ATC of a maneuver in response to a Predictive SS alert

Non-Predictive SS Alerts



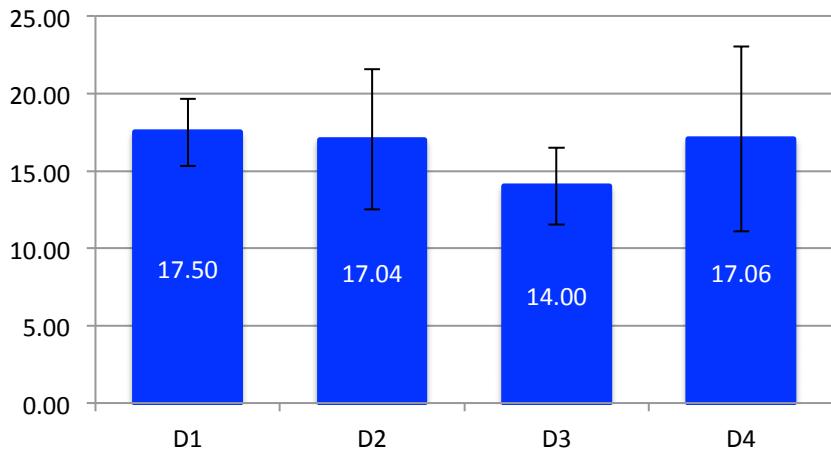
- There was no significant effect of Display on ATC Notification Time for Non-Predictive SS alerts, $p > .05$
- Pilots took an average of **14.52** to notify ATC of a maneuver in response to a Non-Predictive SS alert



ATC Notification Time

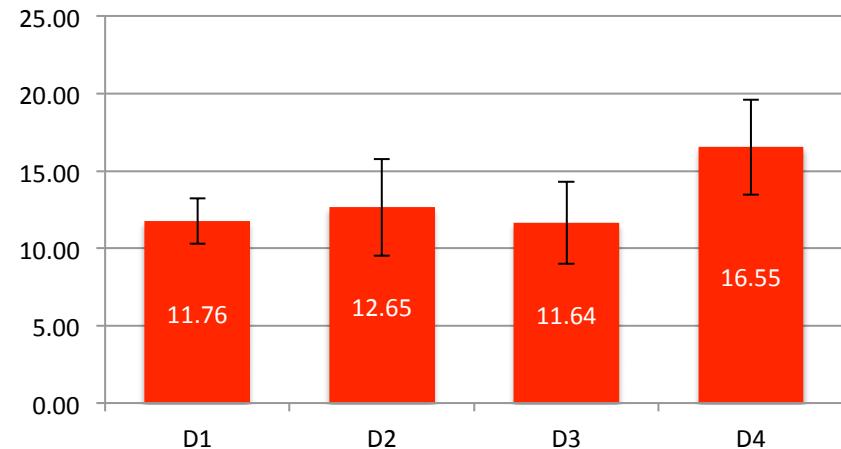


Cooperative SS Alerts



- There was no significant effect of Display on ATC Notification Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **16.40 seconds** to notify ATC of a maneuver in response to a Cooperative SS alert

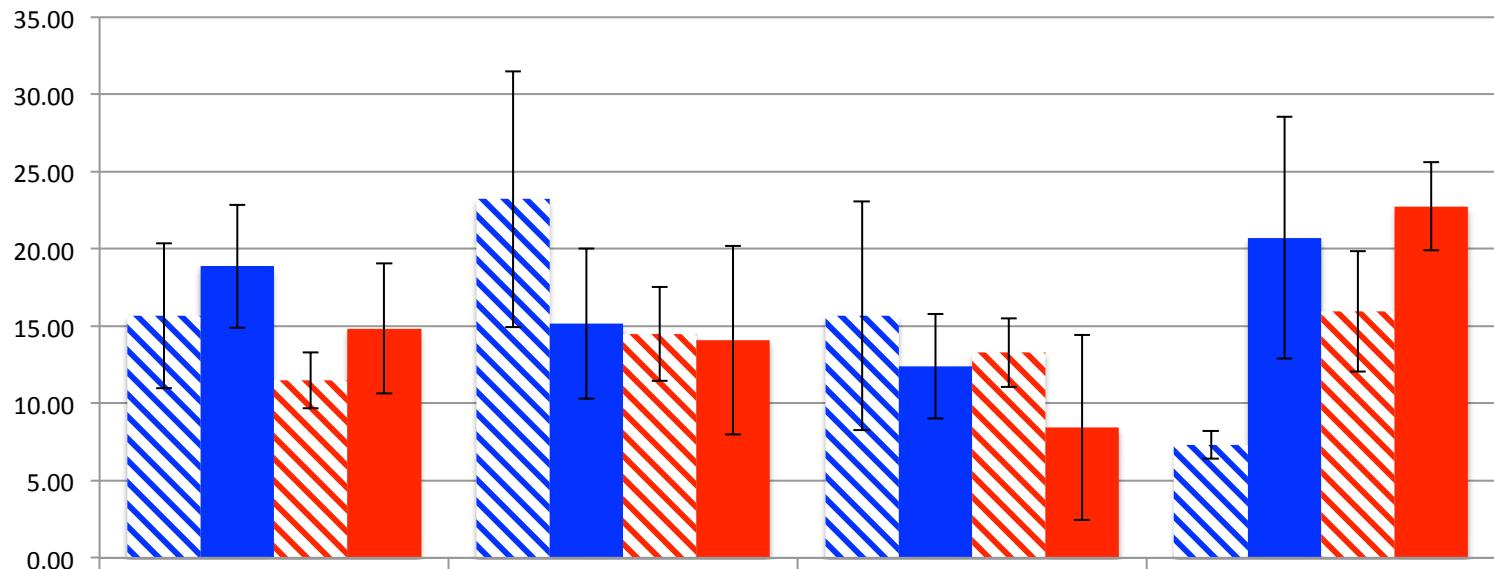
Non-Cooperative SS Alerts



- There was no significant effect of Display on ATC Notification Time for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average of **13.15 seconds** to notify ATC of a maneuver in response to a Non-Cooperative SS alert



ATC Notification Time



Cooperative/Predictive	15.67
Cooperative/Non-Predictive	18.88
Non-Cooperative/Predictive	11.49
Non-Cooperative/Non-Predictive	14.83

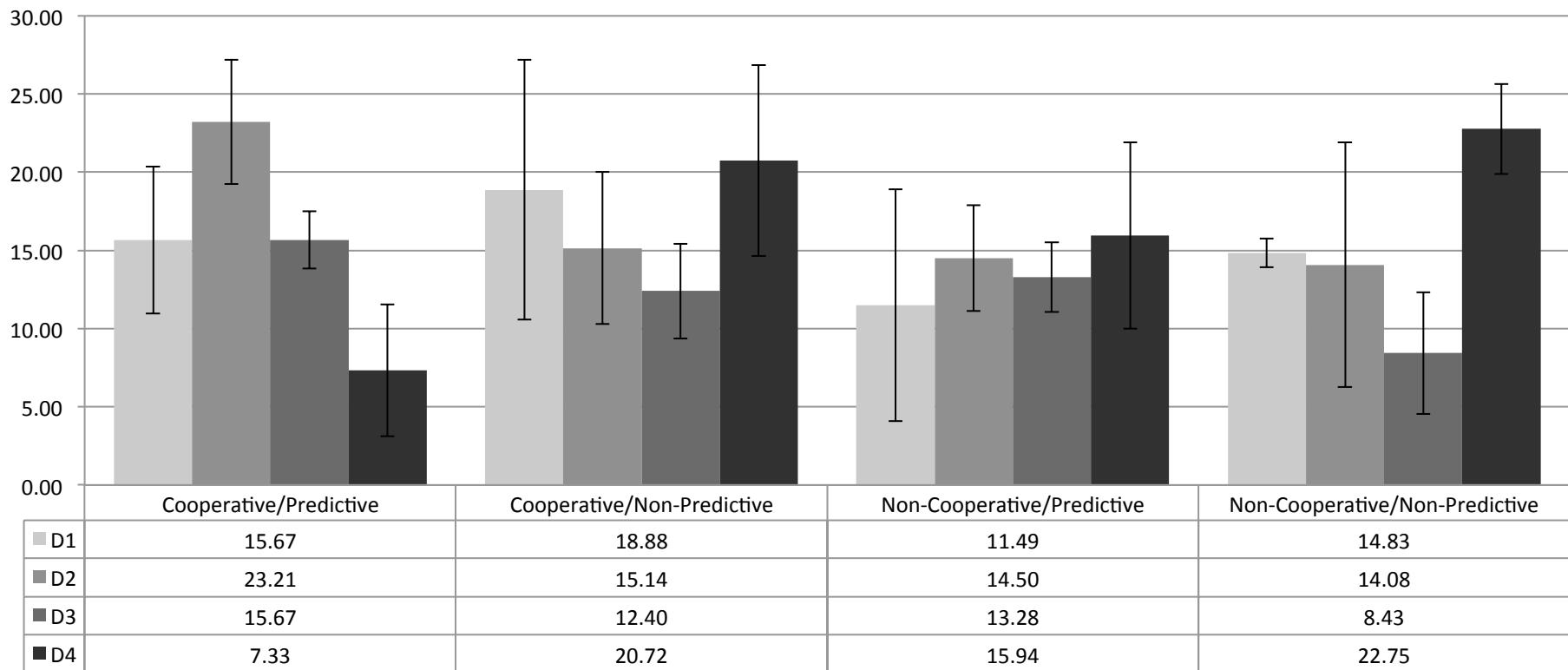
Cooperative/Predictive	23.21
Cooperative/Non-Predictive	15.14
Non-Cooperative/Predictive	14.50
Non-Cooperative/Non-Predictive	14.08

Cooperative/Predictive	15.67
Cooperative/Non-Predictive	12.40
Non-Cooperative/Predictive	13.28
Non-Cooperative/Non-Predictive	8.43

Cooperative/Predictive	7.33
Cooperative/Non-Predictive	20.72
Non-Cooperative/Predictive	15.94
Non-Cooperative/Non-Predictive	22.75



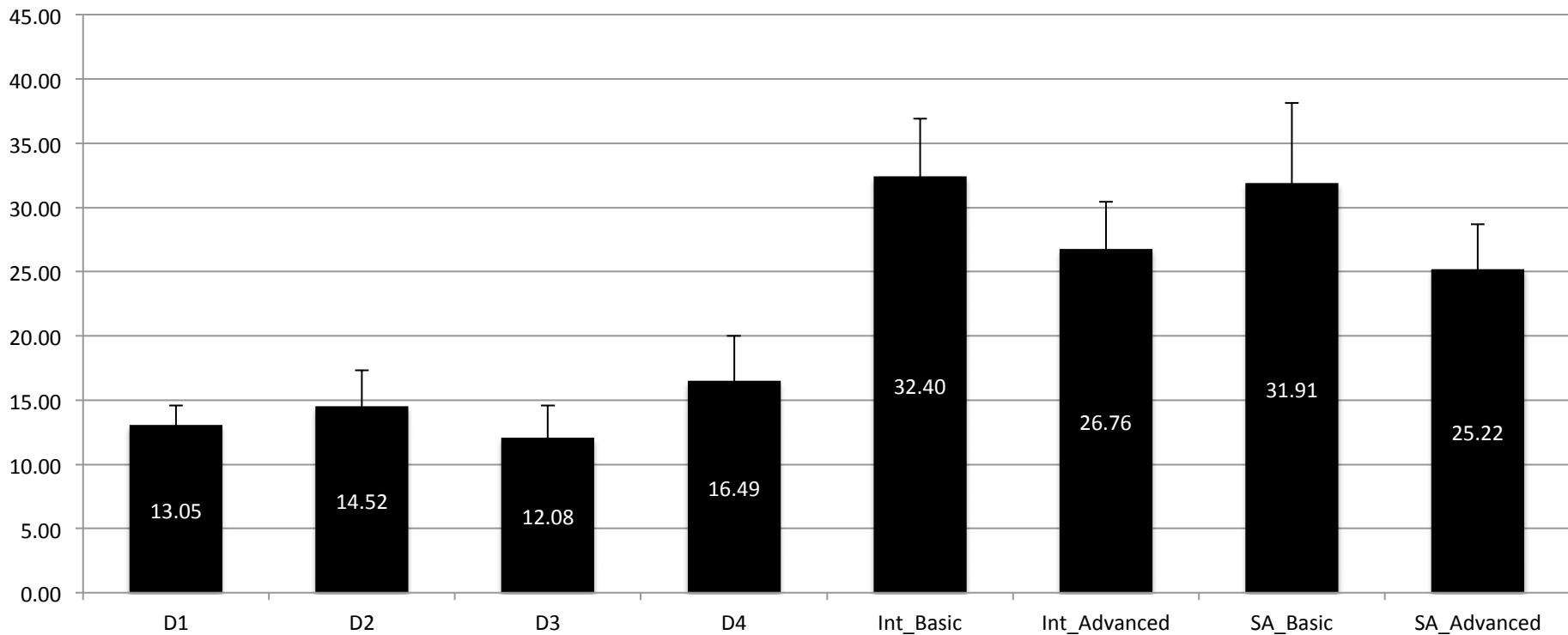
ATC Notification Time





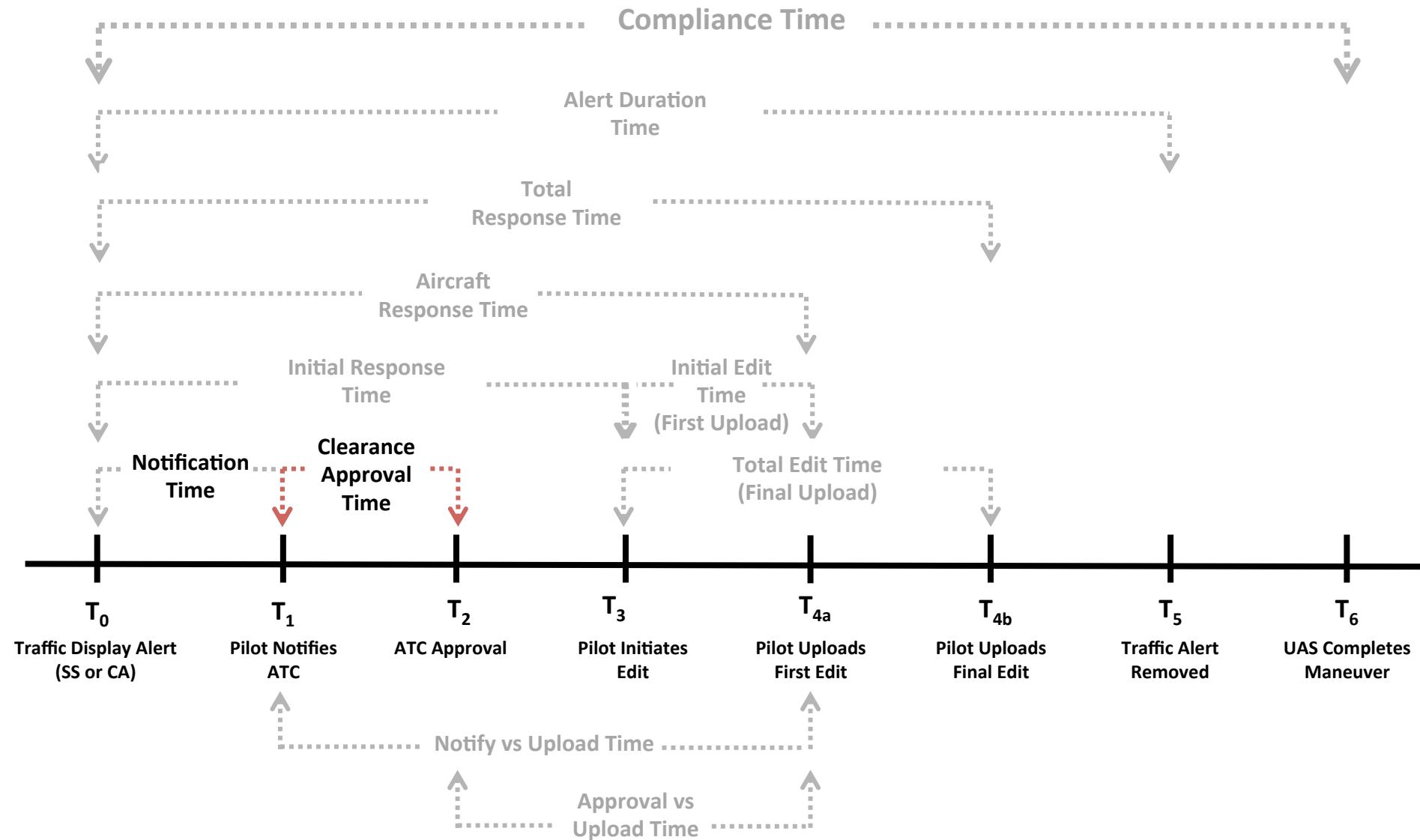
ATC Notification Time

IHTL and PT4 Display Comparison



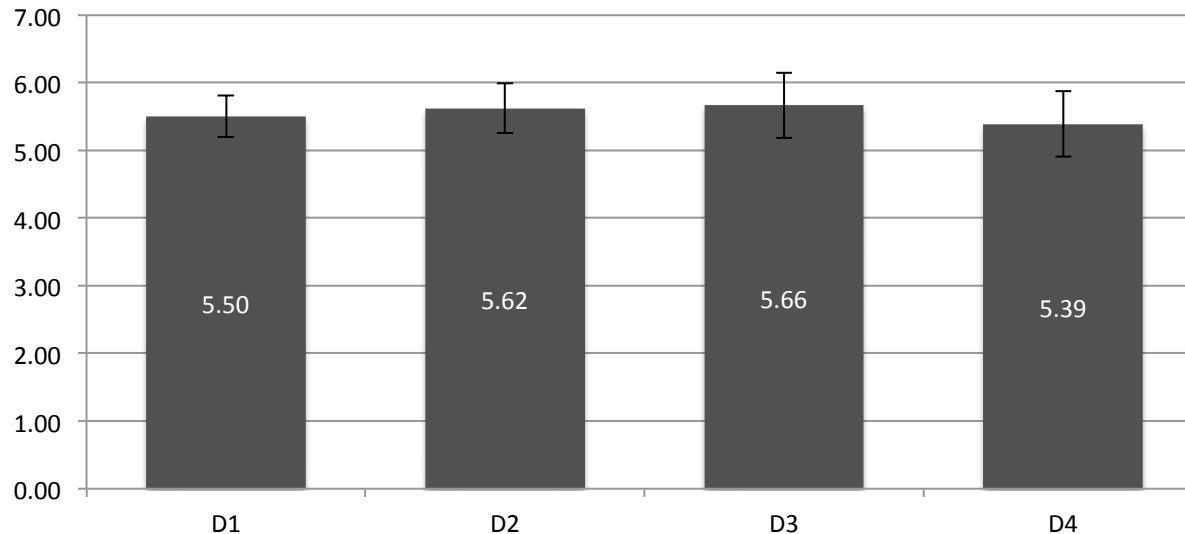


Stages of Pilot DAA Task





Clearance Approval Time

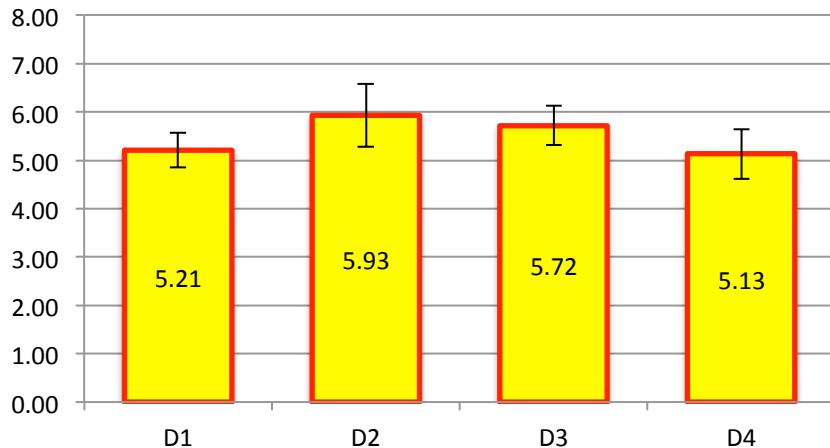


- There was no significant main effect of Information on Clearance Approval Time, $p > .05$
- It took an average of **5.54 seconds** for pilots to receive and an ATC approval for a maneuver in response to a SS alert



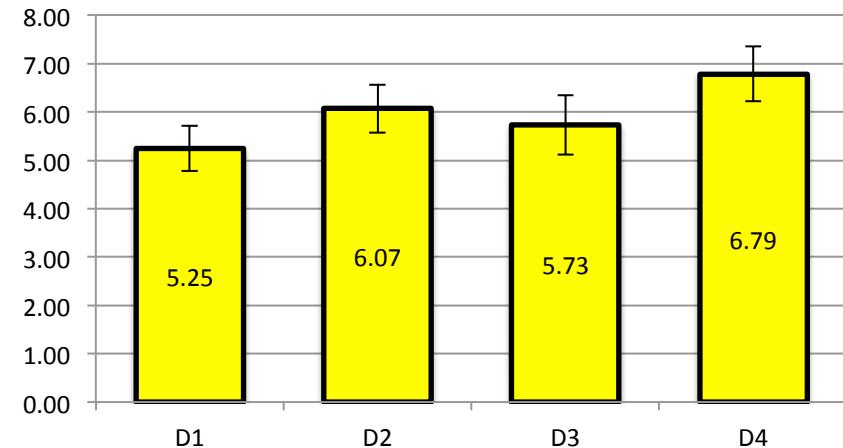
Clearance Approval Time

Predictive SS Alerts



- There was no significant main effect of Information on Clearance Approval Time, $p > .05$
- It took an average of **5.50 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Predictive SS alert

Non-Predictive SS Alerts

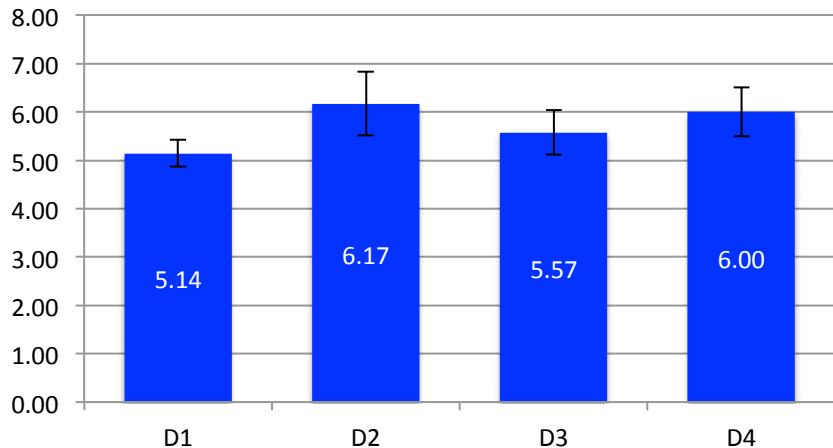


- There was no significant main effect of Display on Clearance Approval Time, $p > .05$
- It took an average of **5.96 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Non-Predictive SS alert



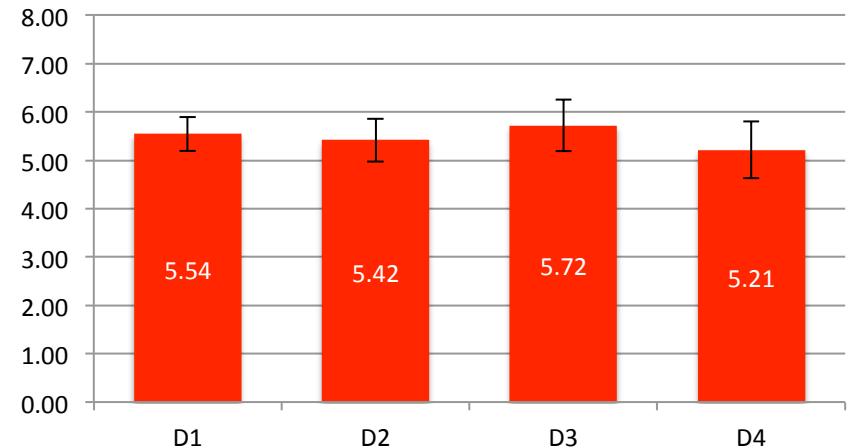
Clearance Approval Time

Cooperative SS Alerts



- There was not a significant effect of Display on Clearance Approval Time for Cooperative SS alerts, $p > .05$
- It took an average of **5.72 seconds** for pilots to receive and an ATC a Cooperative SS alert

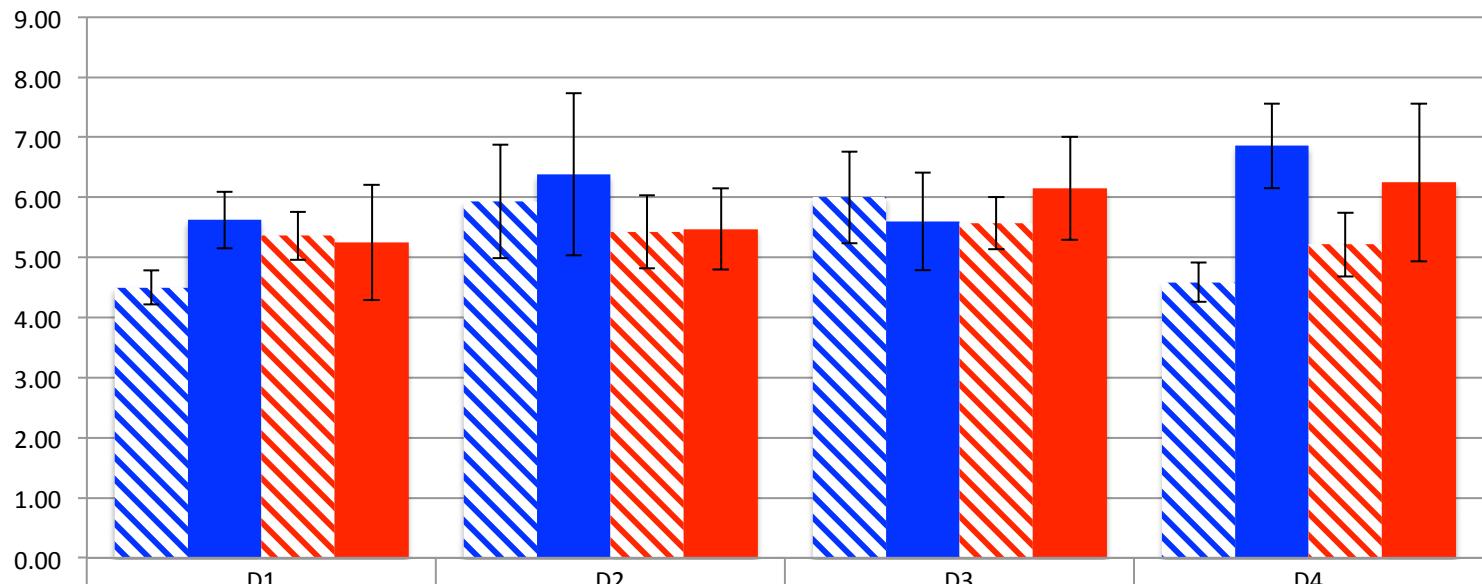
Non-Cooperative SS Alerts



- There was no significant effect of Display on Clearance Approval Time for Non-Cooperative SS alerts, $p > .05$
- It took an average of **5.47 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Non-Cooperative SS alert



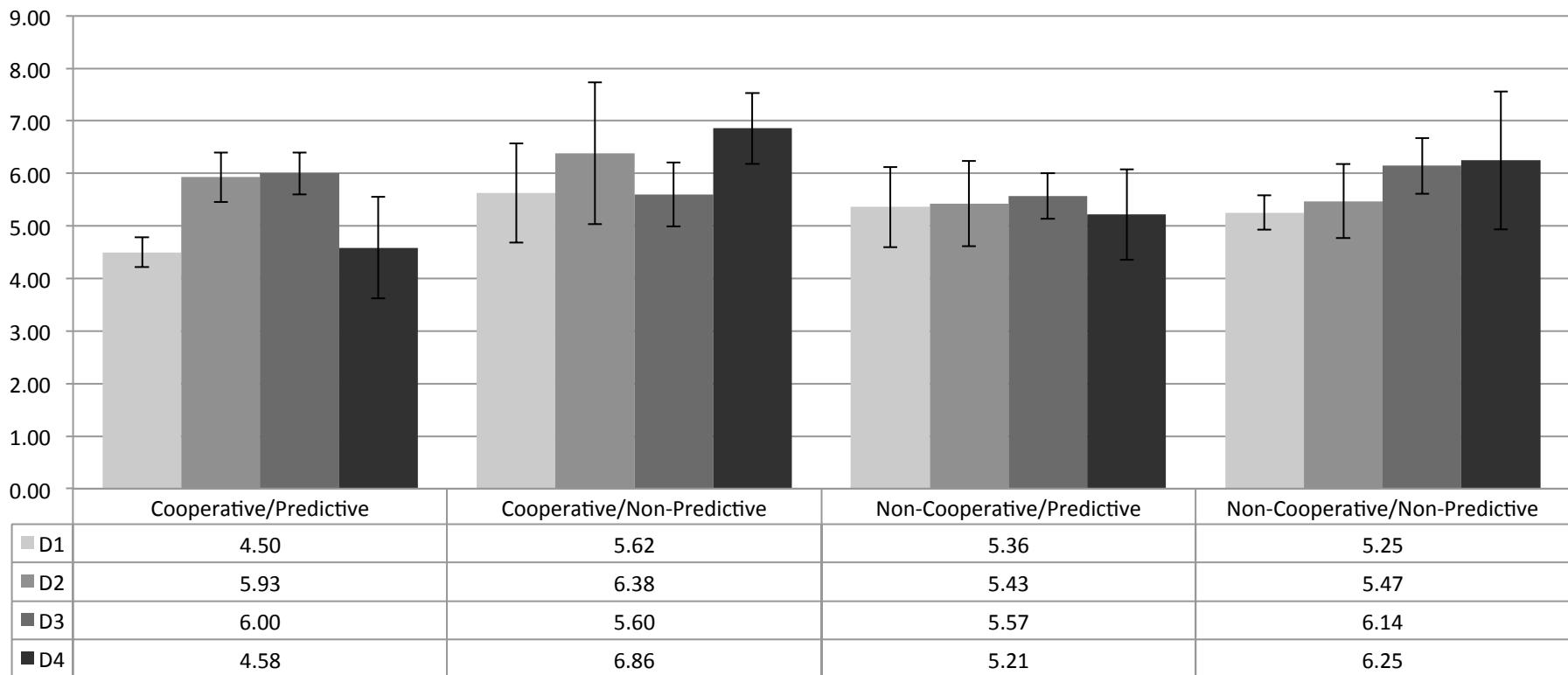
Clearance Approval Time



	D1	D2	D3	D4
Cooperative/Predictive	4.50	5.93	6.00	4.58
Cooperative/Non-Predictive	5.62	6.38	5.60	6.86
Non-Cooperative/Predictive	5.36	5.43	5.57	5.21
Non-Cooperative/Non-Predictive	5.25	5.47	6.14	6.25



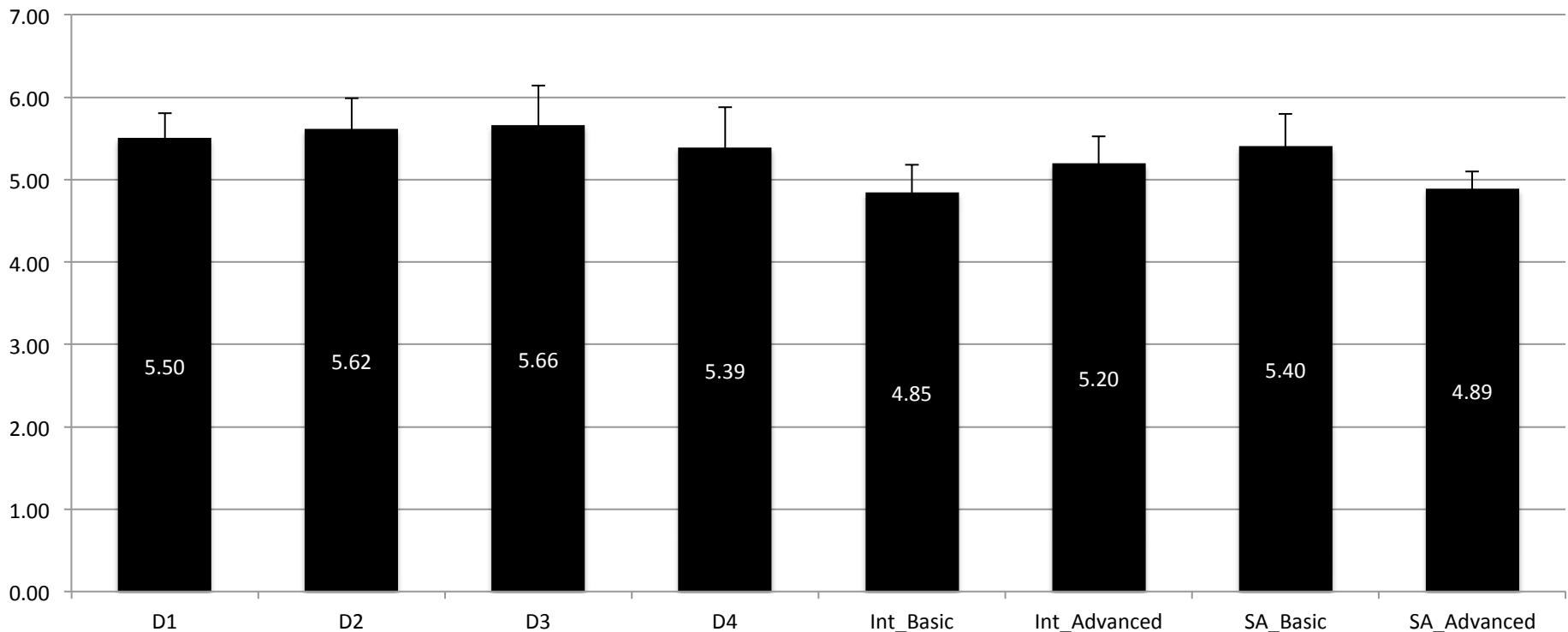
Clearance Approval Time





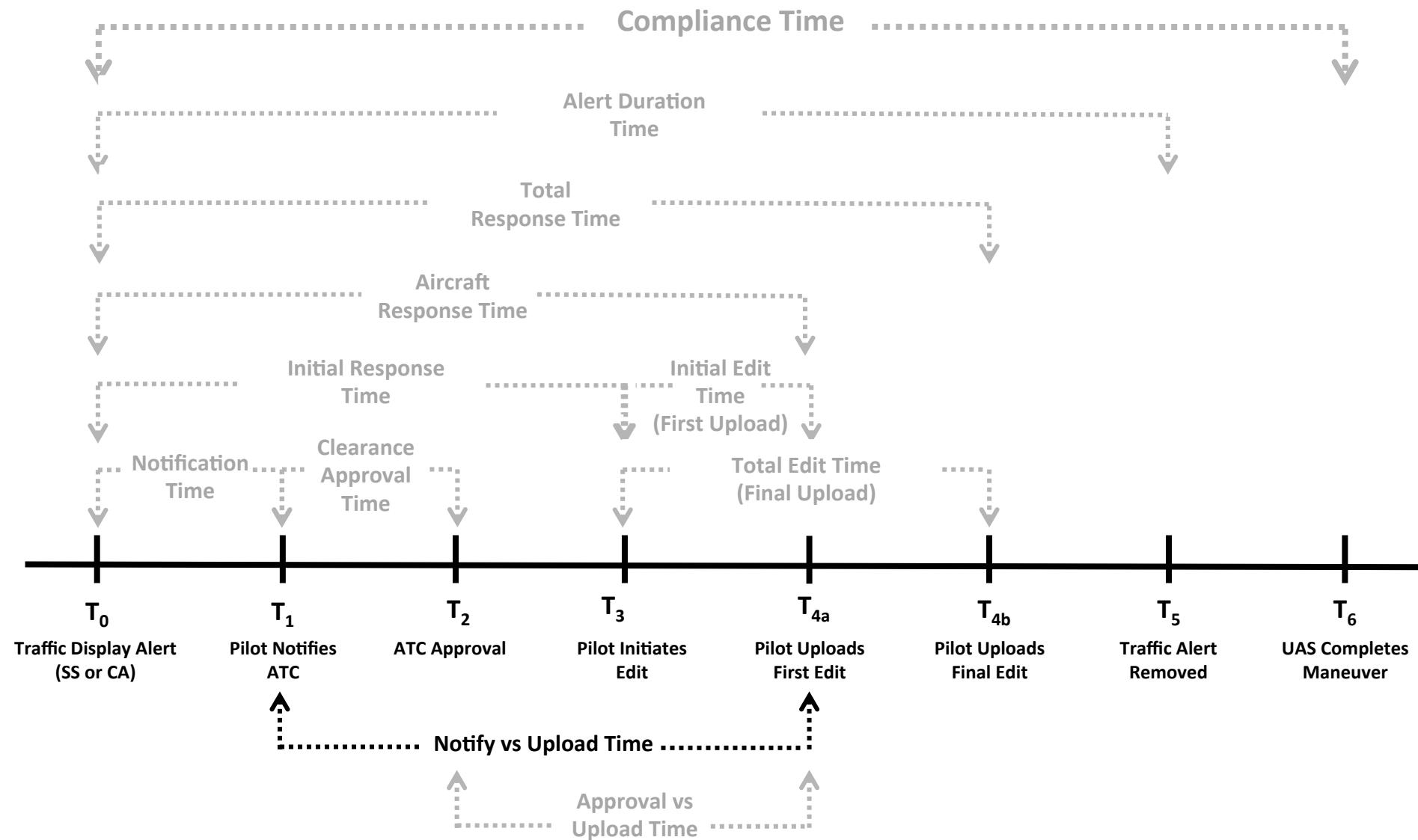
Clearance Approval Time

IHTL and PT4 Display Comparison



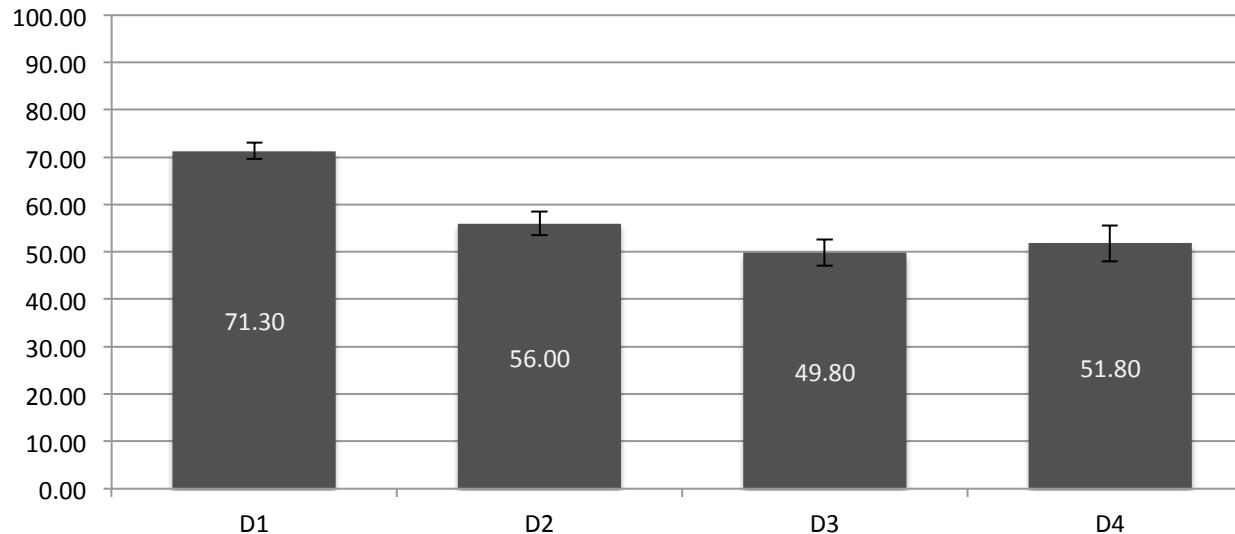


Stages of Pilot DAA Task





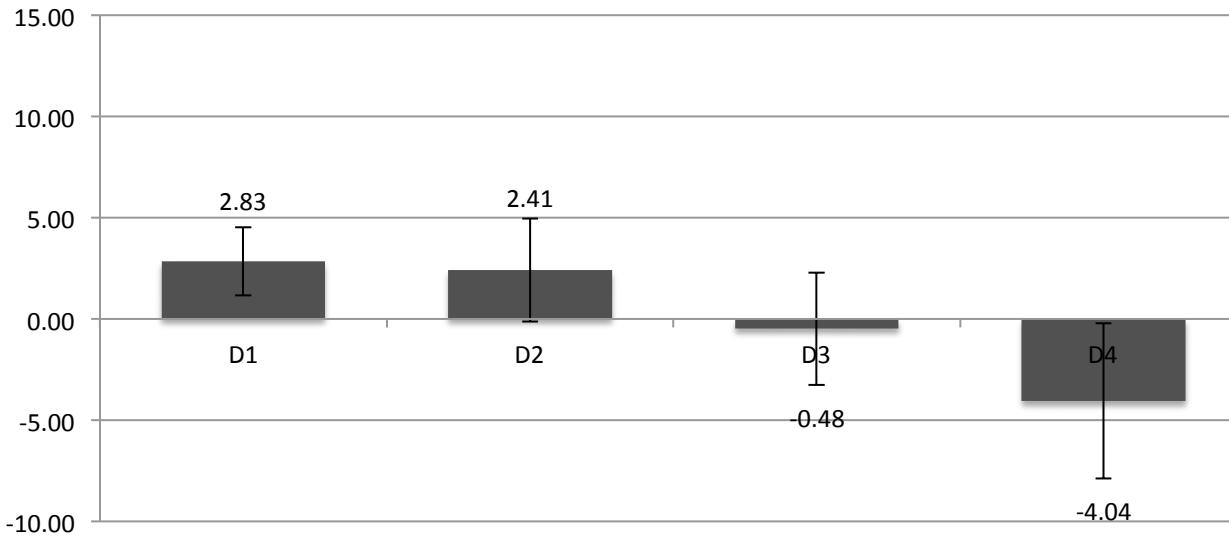
ATC Notification vs Upload Time



- Across all maneuvers, pilots requested a clearance **93.4%** of the time
- On average, pilots who *requested* an ATC clearance did so prior to maneuvering in response to SS alerts **57.2%** of the time (65.1% overall)
 - D1 = 71.3%
 - D2 = 56.0%
 - D3 = 49.8%
 - D4 = 51.8%



ATC Notification vs Upload Time

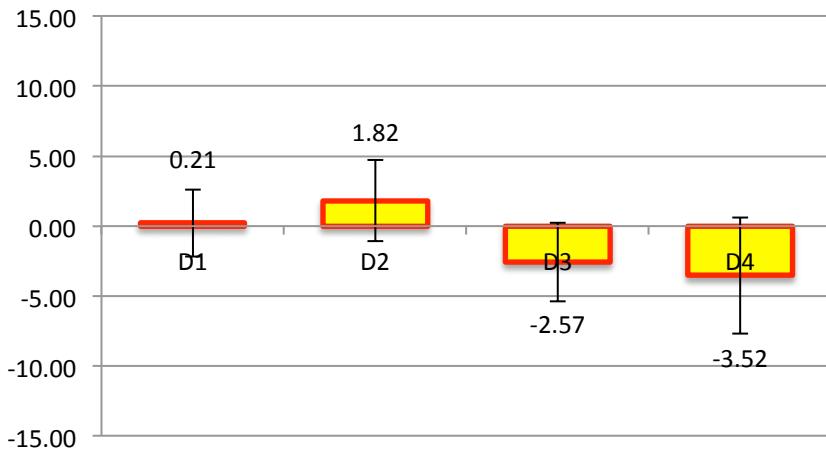


- There was a near significant effect of Display on ATC Notification vs Upload Time for all SS alerts, $p = .075$
- On average, pilots *requested* an ATC clearance **0.18 seconds prior to** uploading a maneuver in response to a Predictive SS alert



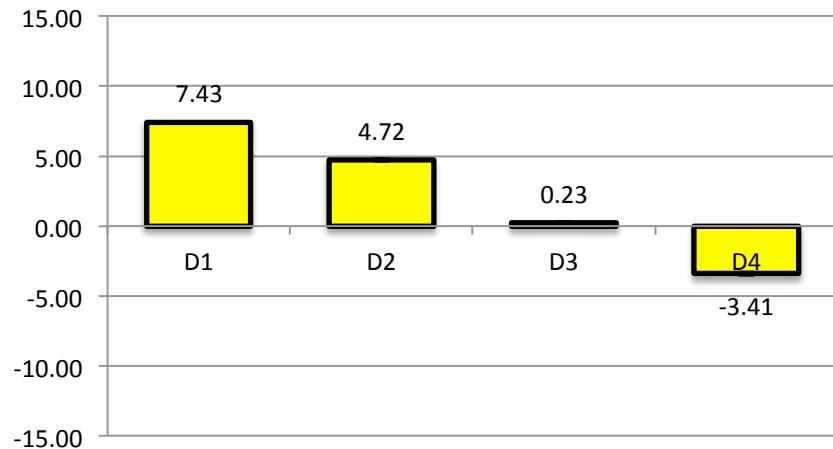
ATC Notification vs Upload Time

Predictive SS Alerts



- There was no significant effect of Display on ATC Notification vs Upload Time for Predictive SS alerts, $p > .05$
- On average, pilots *requested* an ATC clearance **1.01 sec after** uploading a maneuver in response to a Predictive SS alert

Non-Predictive SS Alerts



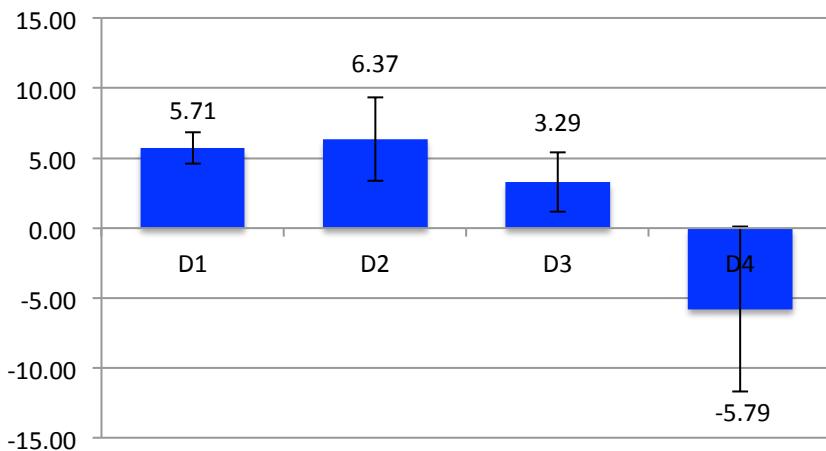
- There was a significant effect of Display on ATC Notification vs Upload Time for Non-Predictive SS alerts, $p < .05$
 - No differences between displays were significant
- On average, pilots *requested* an ATC clearance **2.24 seconds prior** to uploading a maneuver in response to a Non-Predictive SS alert



ATC Notification vs Upload Time

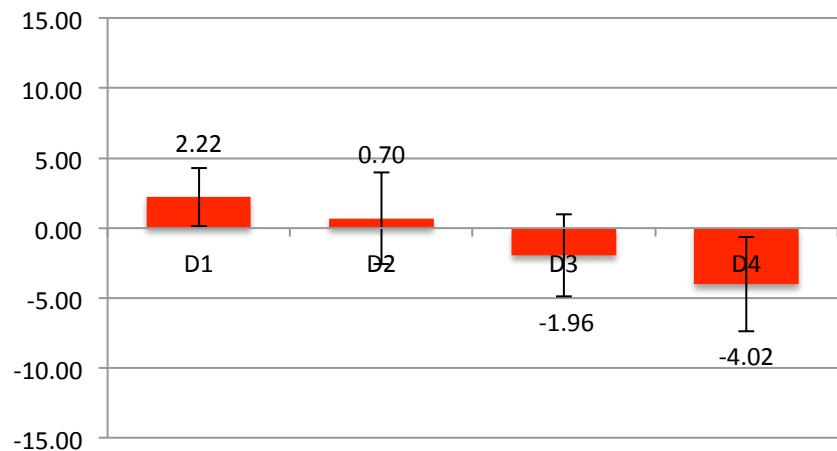


Cooperative SS Alerts



- There was a near significant effect of Information on ATC Notification vs Upload Time for Cooperative SS alerts, $p = .055$
- On average, pilots *requested* an ATC clearance **2.40 seconds prior** to uploading a maneuver in response to a Cooperative SS alert

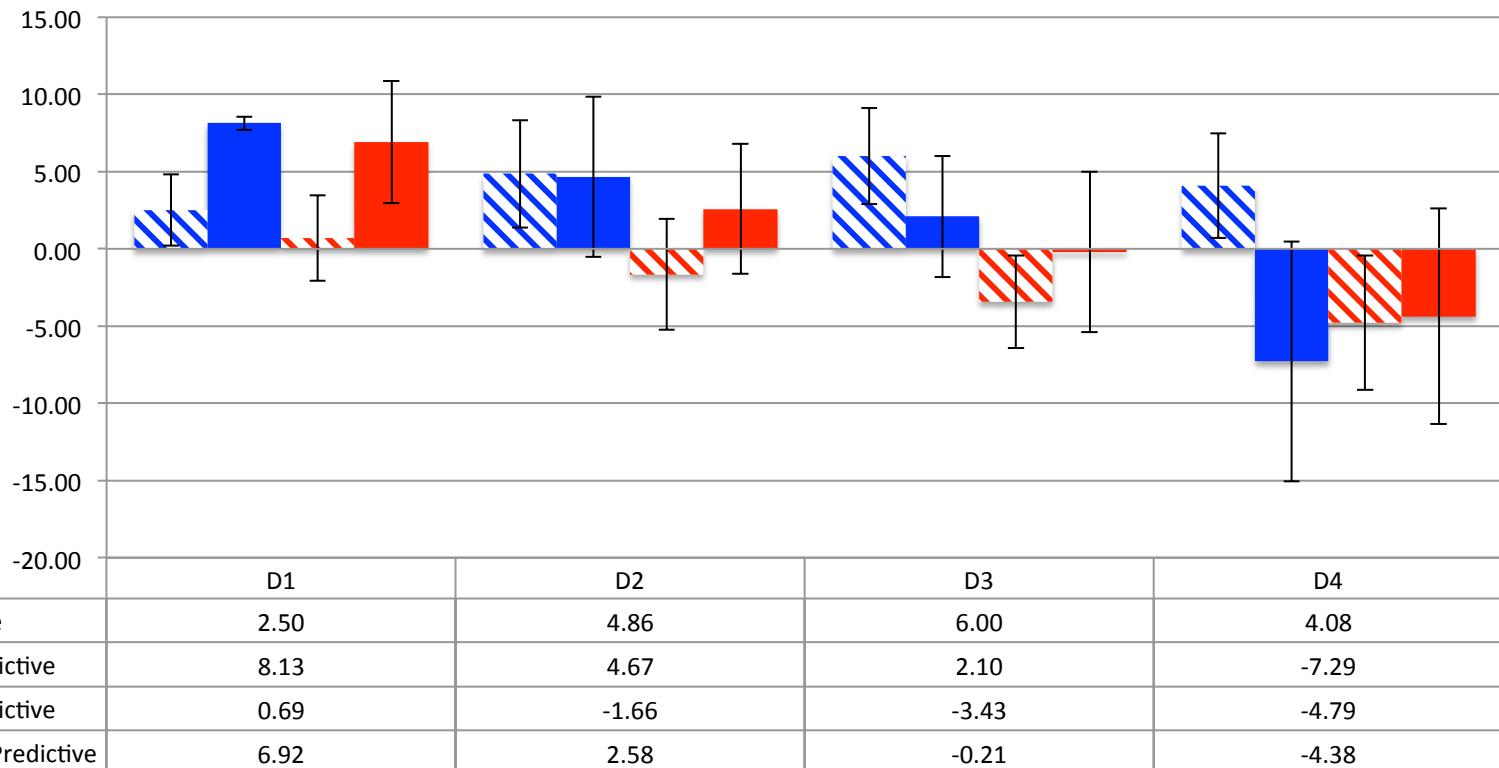
Non-Cooperative SS Alerts



- There was no significant effect of Display on ATC Notification vs Upload Time for Non-Cooperative SS alerts, $p > .05$
- On average, pilots *requested* an ATC clearance **0.76 seconds after** uploading a maneuver in response to a Non-Cooperative alert

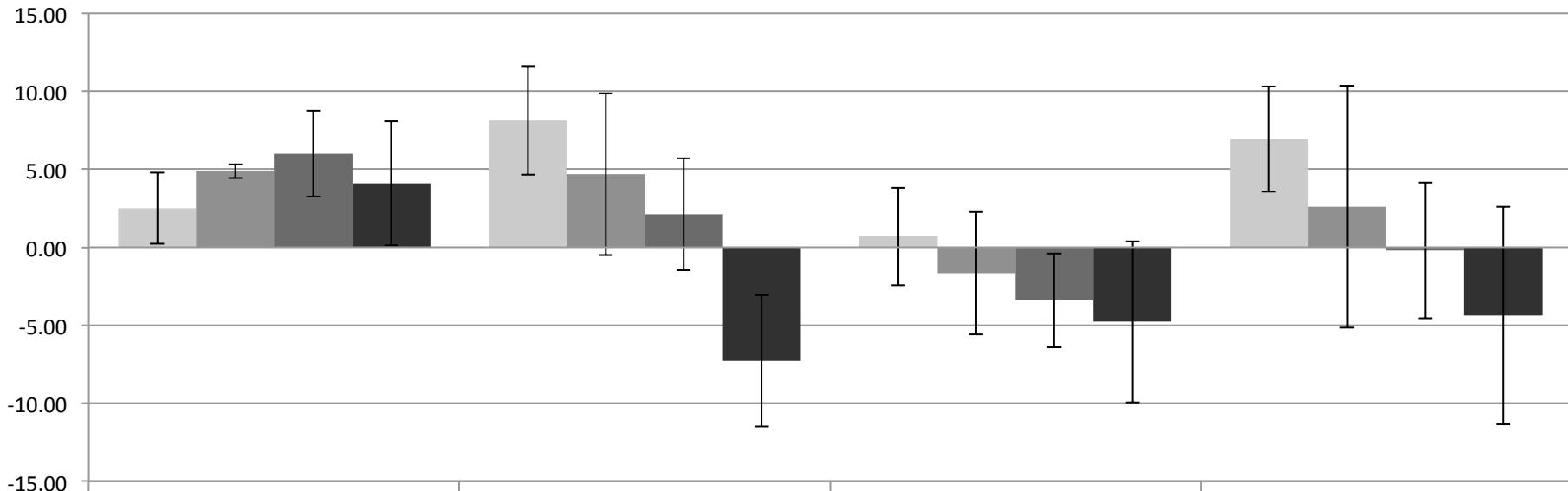


ATC Notification vs Upload Time





ATC Notification vs Upload Time

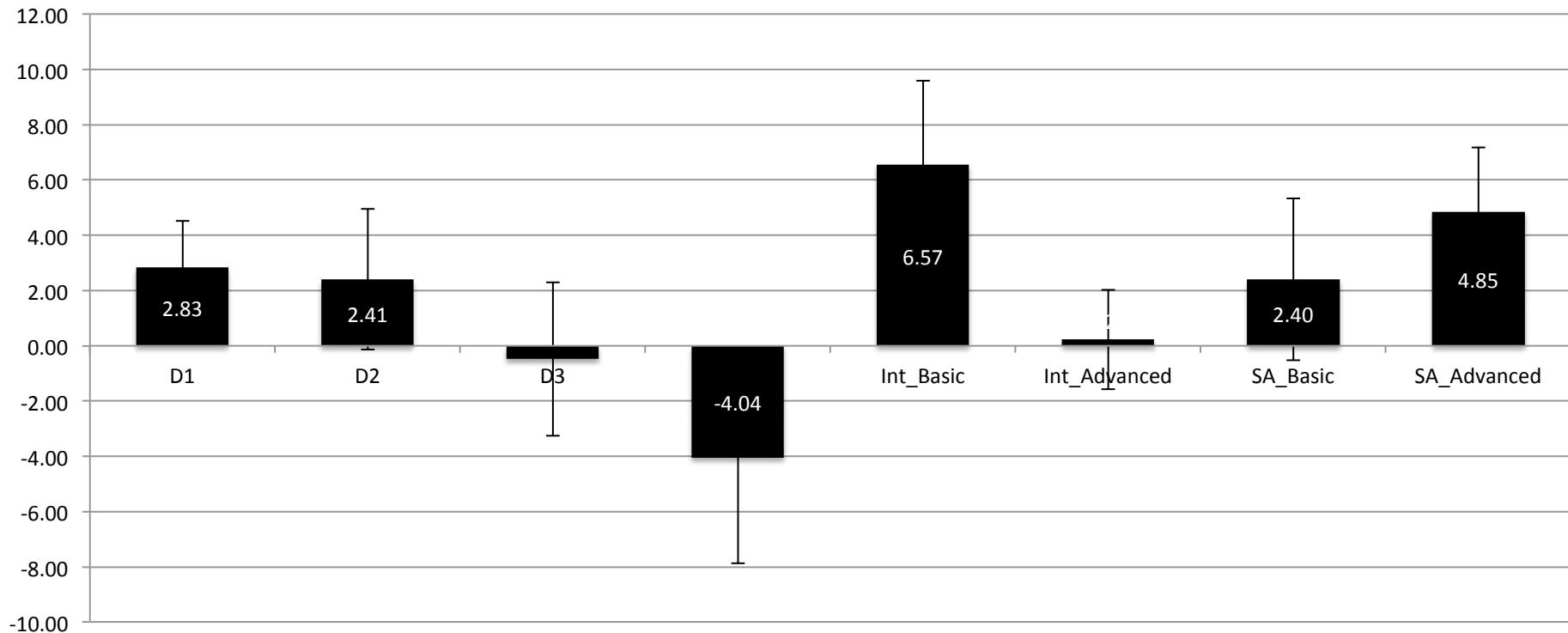


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	2.50	8.13	0.69	6.92
D2	4.86	4.67	-1.66	2.58
D3	6.00	2.10	-3.43	-0.21
D4	4.08	-7.29	-4.79	-4.38



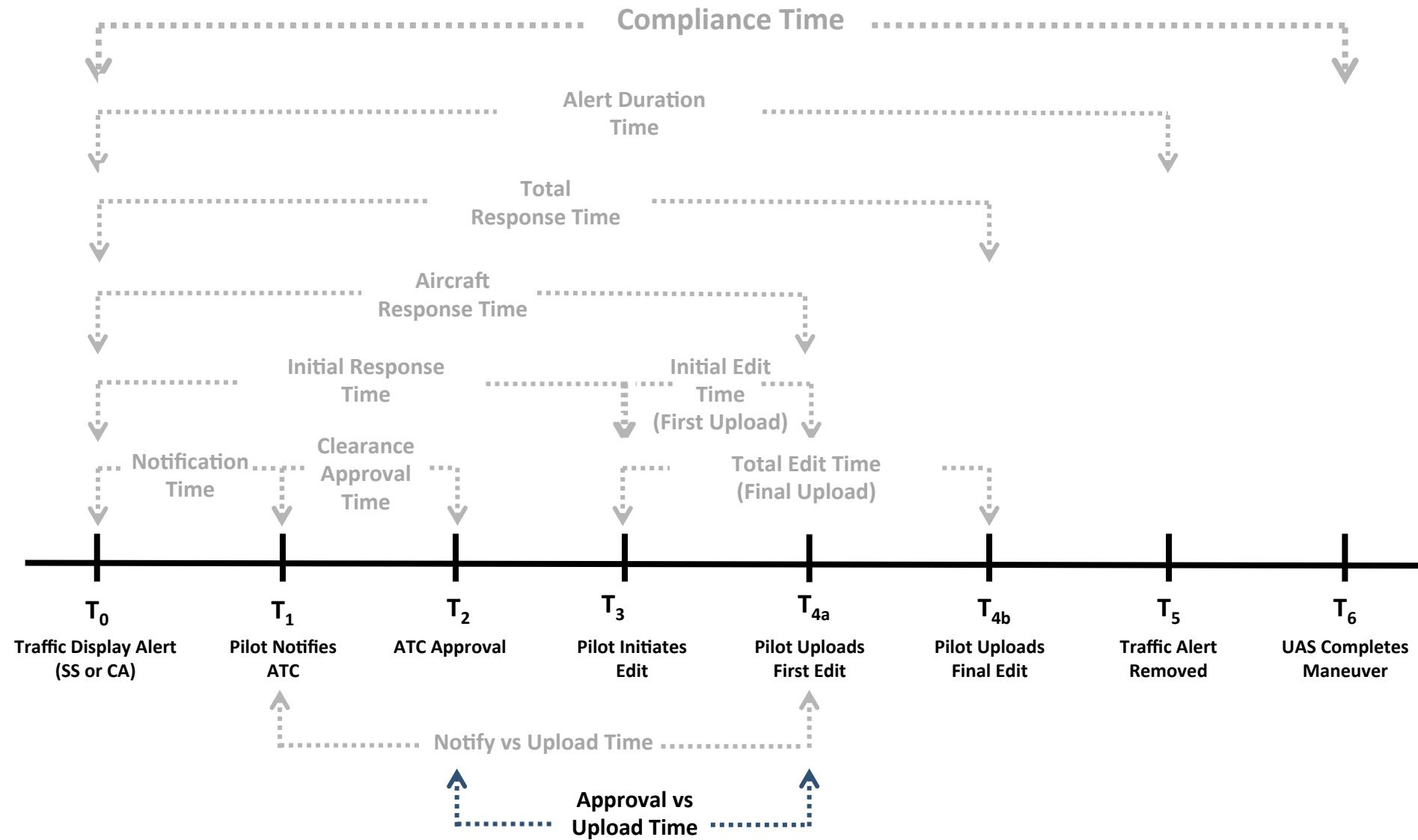
ATC Notification vs Upload Time

IHTML and PT4 Display Comparison



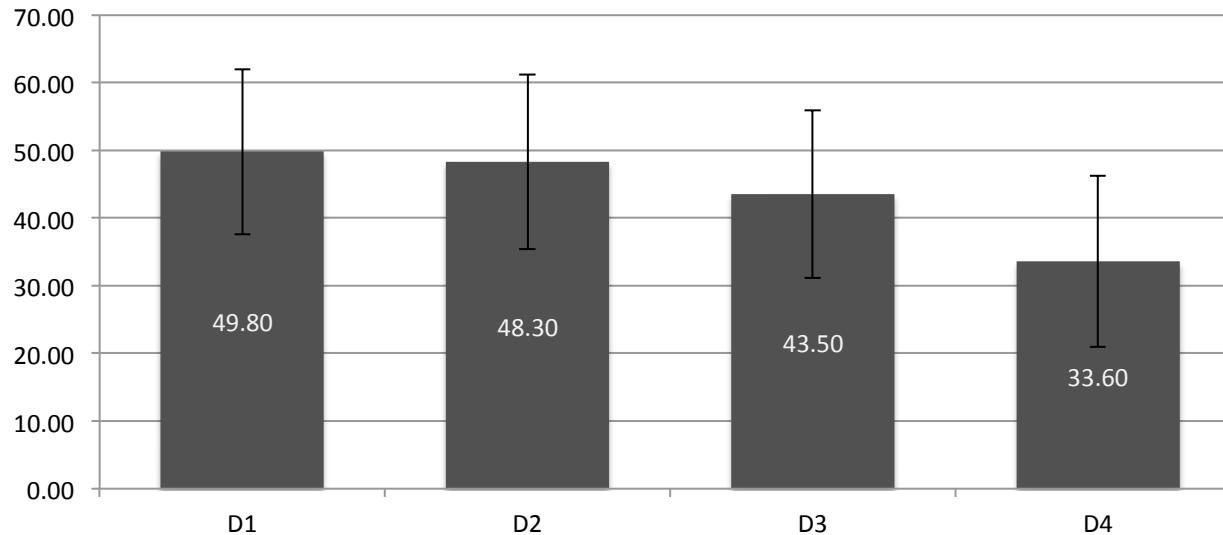


Stages of Pilot DAA Task





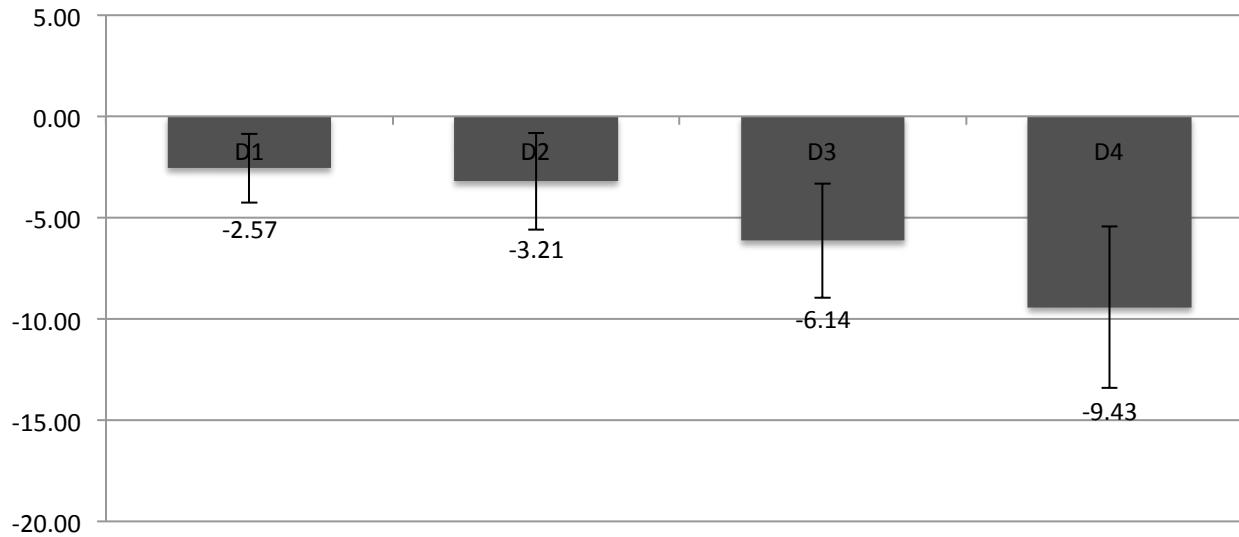
ATC Approval vs Upload Time



- Across all maneuvers, pilots received a clearance **92.9%** of the time
- On average, pilots who *received* an ATC clearance, did so prior to maneuvering in response to SS alerts **56.2%** of the time (62.8% overall)
 - D1 = 49.8%
 - D2 = 48.3%
 - D3 = 43.5%
 - D4 = 33.6%



ATC Approval vs Upload Time

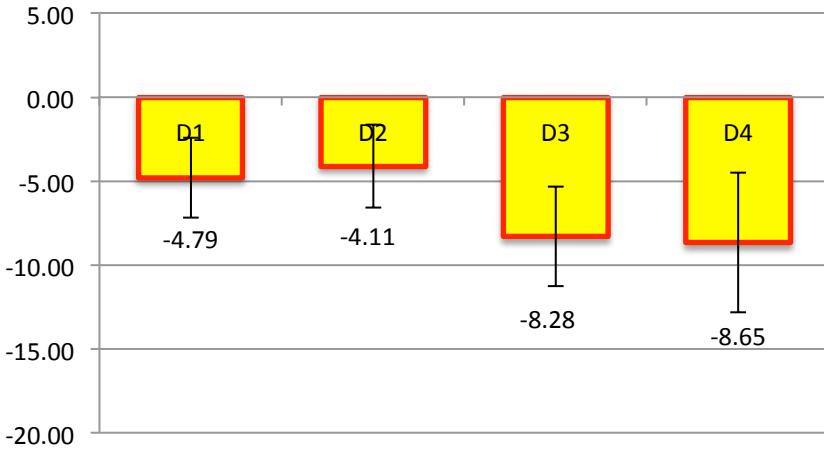


- There was a near significant effect of Display on ATC Approval vs Upload Time for all SS alerts, $p = .092$
- On average, pilots *received* an ATC clearance **6.46 seconds after** uploading a maneuver in response to a Predictive SS alert



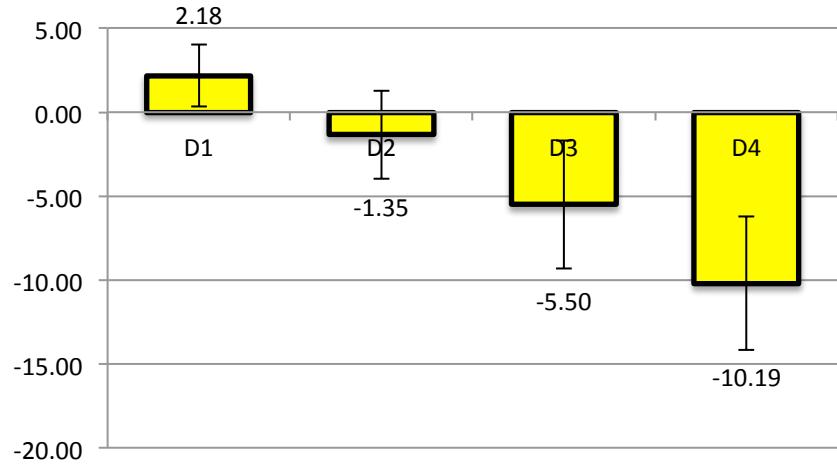
ATC Approval vs Upload Time

Predictive SS Alerts



- There was no significant effect of Display on ATC Approval vs Upload Time for Predictive SS alerts, $p > .05$
- On average, pilots *received* an ATC clearance **6.46 seconds after** uploading a maneuver in response to a Predictive SS alert

Non-Predictive SS Alerts

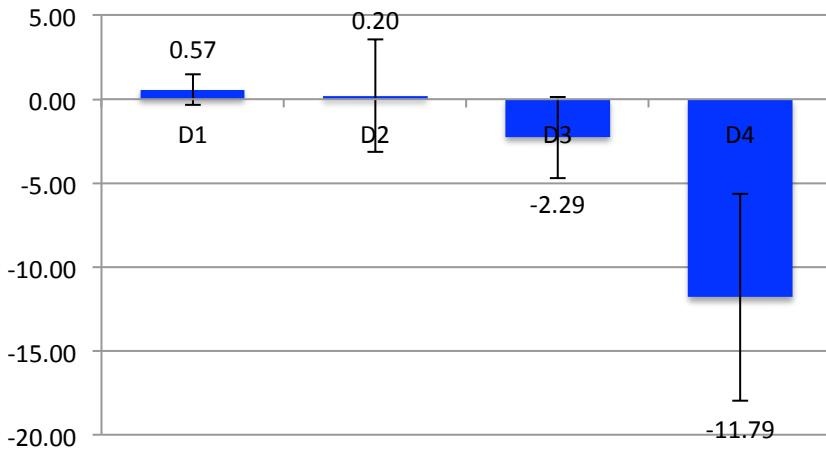


- There was a significant effect of Display on ATC Approval vs Upload Time for Non-Predictive SS alerts, $p < .05$
 - No differences between displays were significant
- On average, pilots *received* an ATC clearance **3.71 seconds after** uploading a maneuver in response to a Non-Predictive SS alert



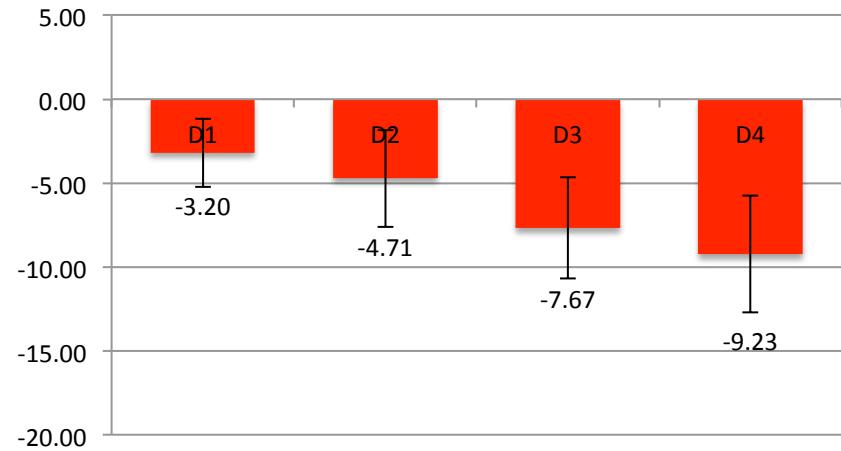
ATC Approval vs Upload Time

Cooperative SS Alerts



- There was a near significant effect of Display on ATC Approval vs Upload Time for Cooperative SS alerts, $p = .070$
- On average, pilots *received* an ATC clearance **3.33 seconds after** uploading a maneuver in response to a Cooperative SS alert

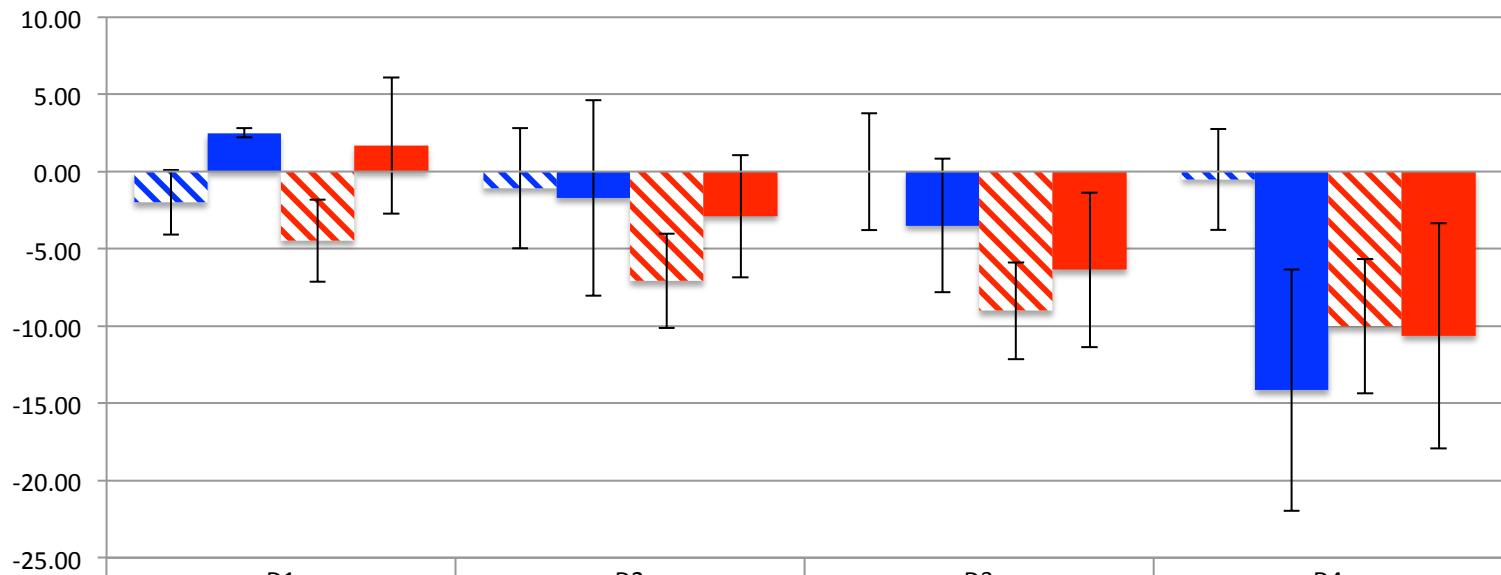
Non-Cooperative SS Alerts



- There was no significant effect of Display on ATC Approval vs Upload Time for Non-Cooperative SS alerts, $p > .05$
- On average, pilots *received* an ATC clearance **6.20 seconds after** uploading a maneuver in response to a Non-Cooperative SS alert



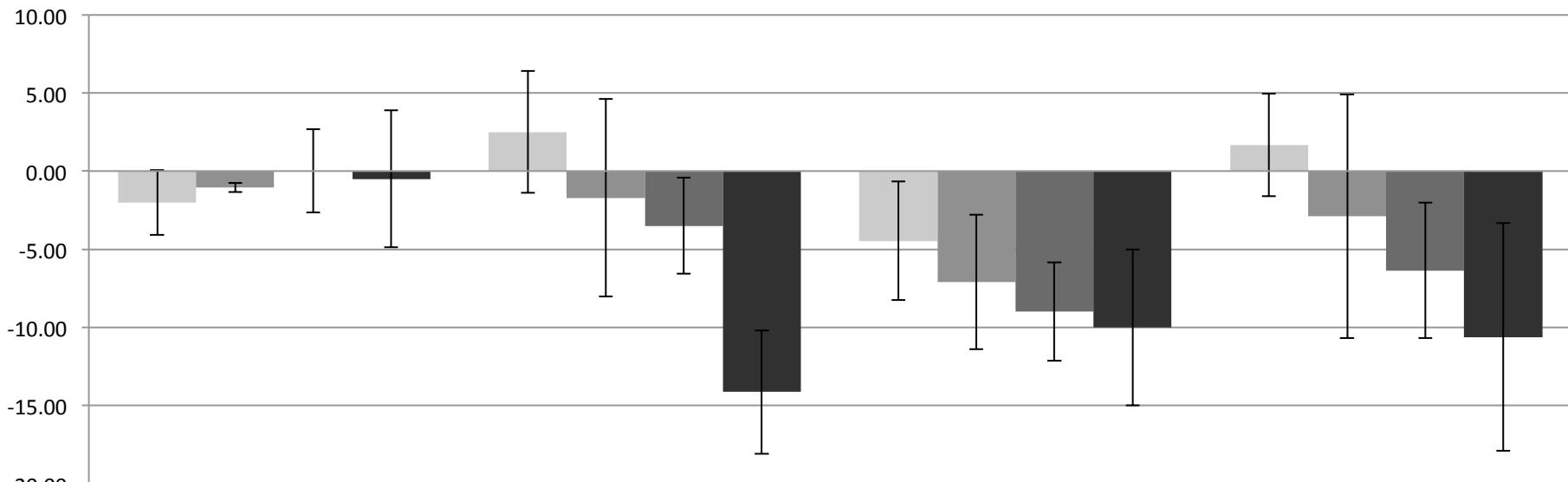
ATC Approval vs Upload Time



	D1	D2	D3	D4
Cooperative/Predictive	-2.00	-1.07	0.00	-0.50
Cooperative/Non-Predictive	2.50	-1.71	-3.50	-14.14
Non-Cooperative/Predictive	-4.47	-7.08	-9.00	-10.00
Non-Cooperative/Non-Predictive	1.67	-2.89	-6.36	-10.63



ATC Approval vs Upload Time

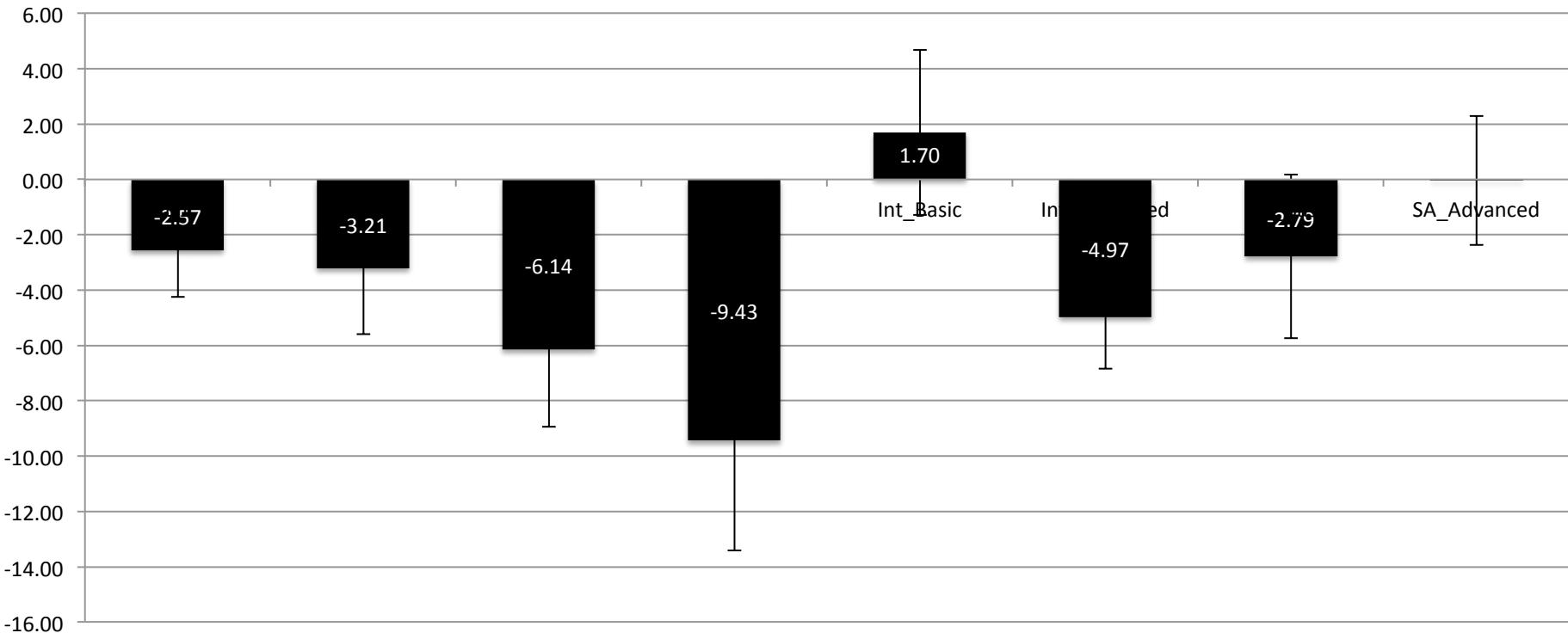


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	-2.00	2.50	-4.47	1.67
D2	-1.07	-1.71	-7.08	-2.89
D3	0.00	-3.50	-9.00	-6.36
D4	-0.50	-14.14	-10.00	-10.63



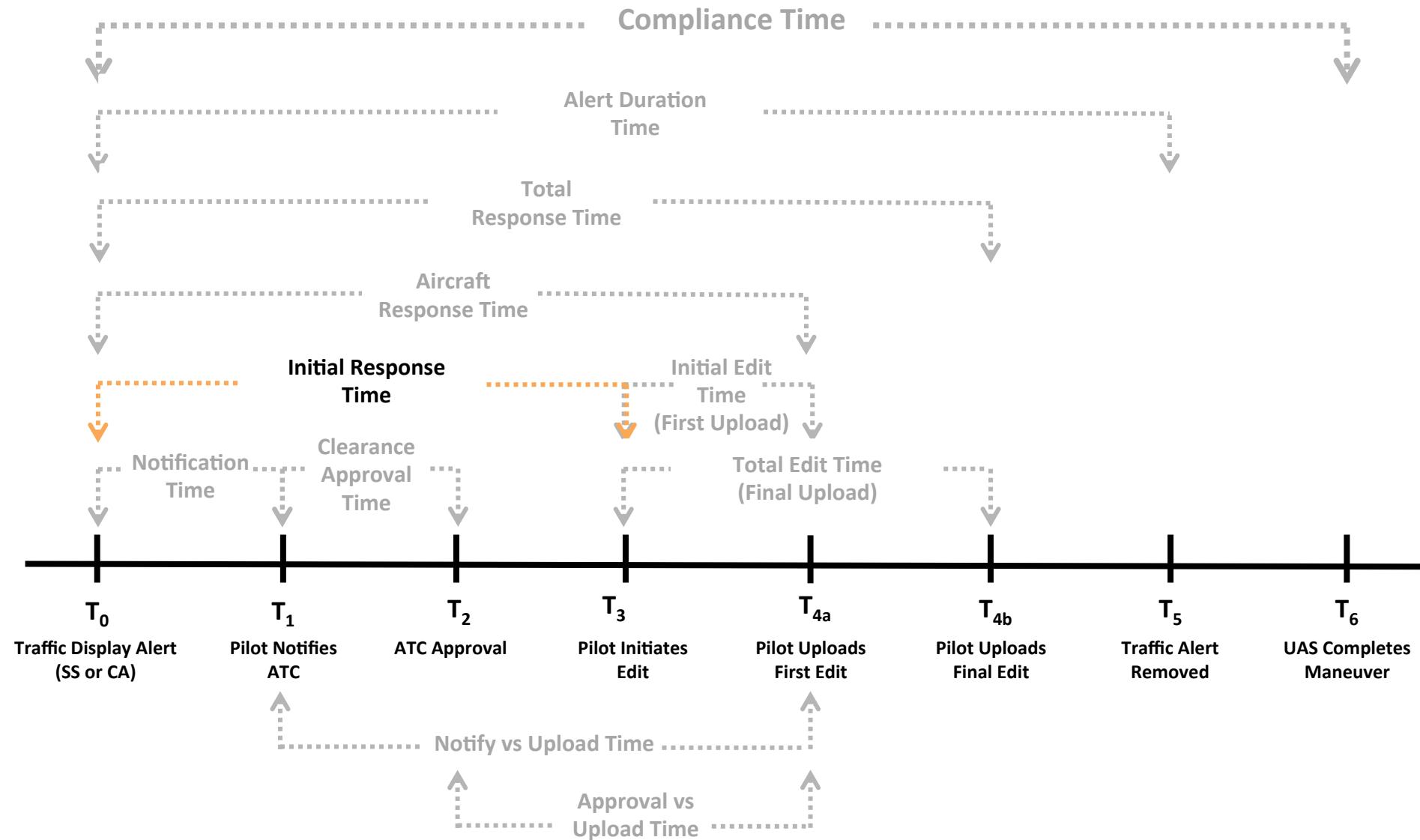
ATC Approval vs Upload Time

IHTL and PT4 Display Comparison



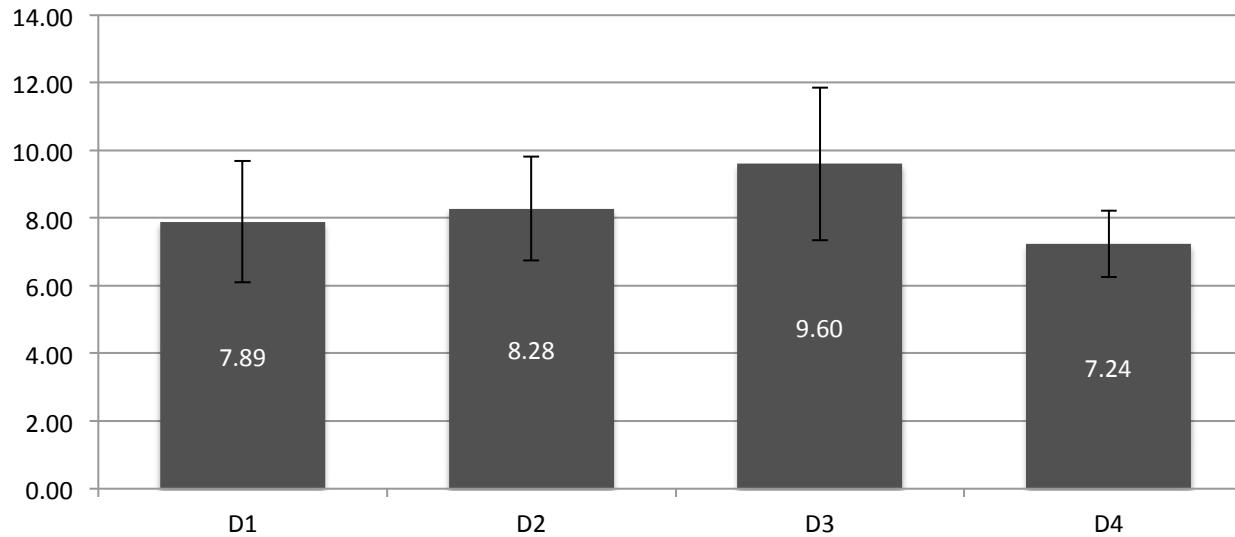


Stages of Pilot DAA Task





Initial Response Time



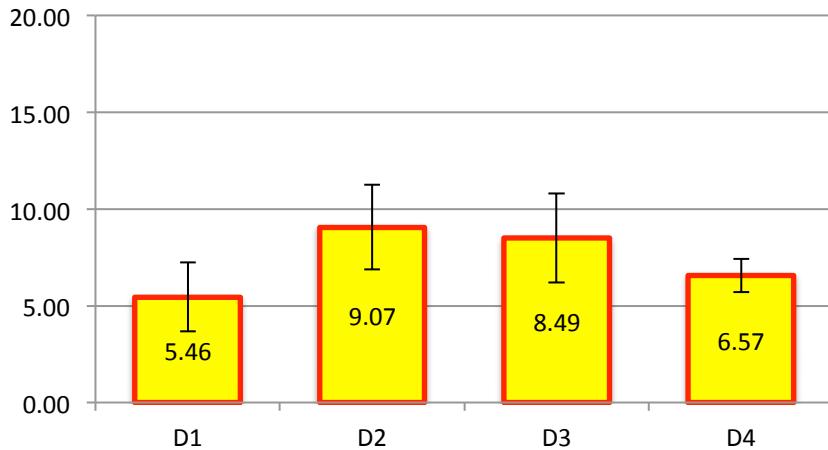
- There was no significant effect of Display on Initial Response Time for all SS alerts, $p > .05$
- Pilots took an average of **8.25 seconds** to initiate an edit in response to a Predictive SS alert



Initial Response Time

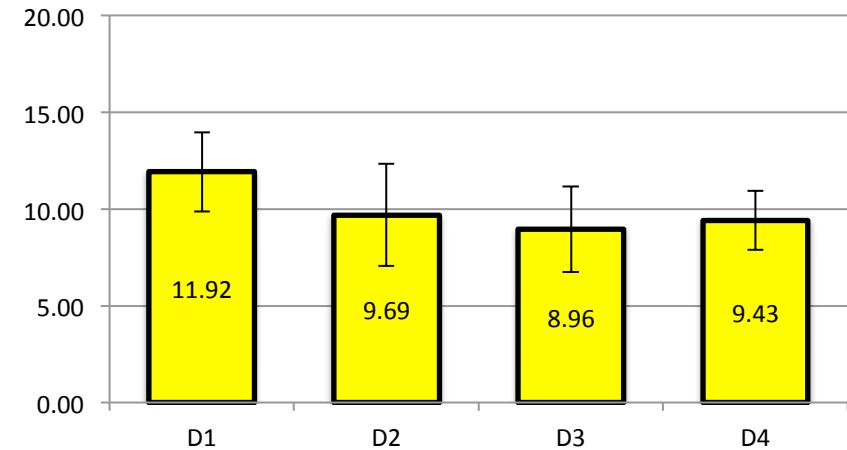


Predictive SS Alerts



- There was no significant effect of Display on Initial Response Time for Predictive SS alerts, $p > .05$
- Pilots took an average of **7.40 seconds** to initiate an edit in response to a Predictive SS alert

Non-Predictive SS Alerts



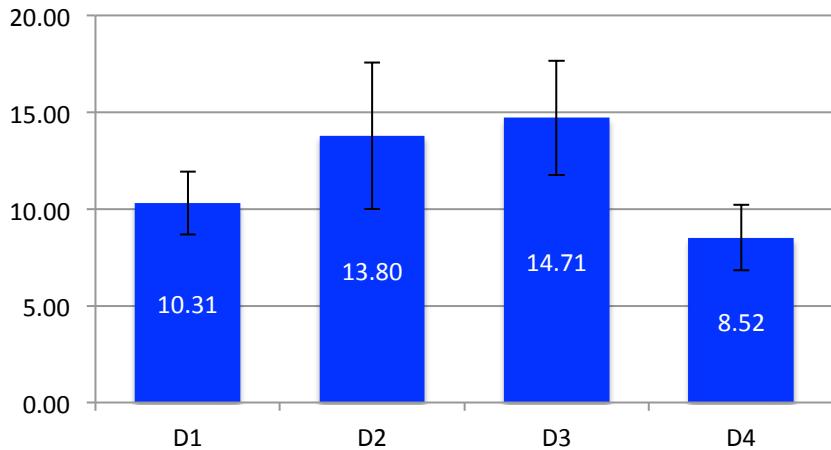
- There was no significant effect of Display on Initial Response Time for Non-Predictive SS alerts, $p > .05$
- Pilots took an average of **10.00 seconds** to initiate an edit in response to a Non-Predictive SS alert



Initial Response Time

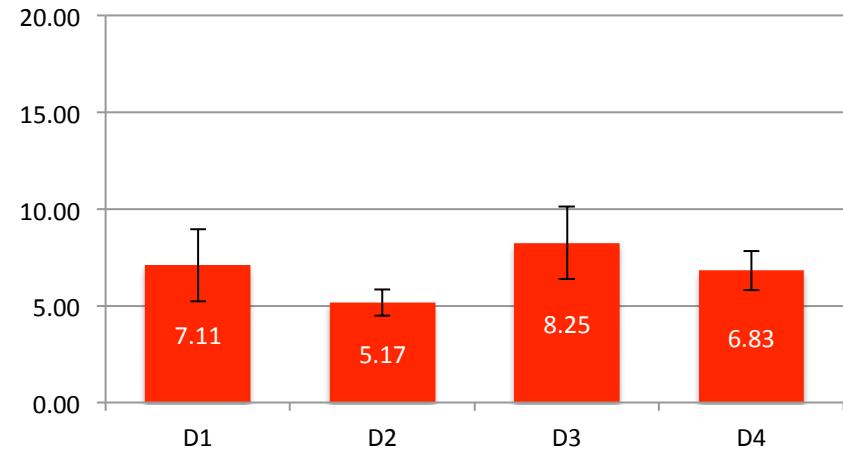


Cooperative SS Alerts



- There was no significant effect of Display on Initial Response Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **11.84 seconds** to initiate an edit in response to a Cooperative SS alert

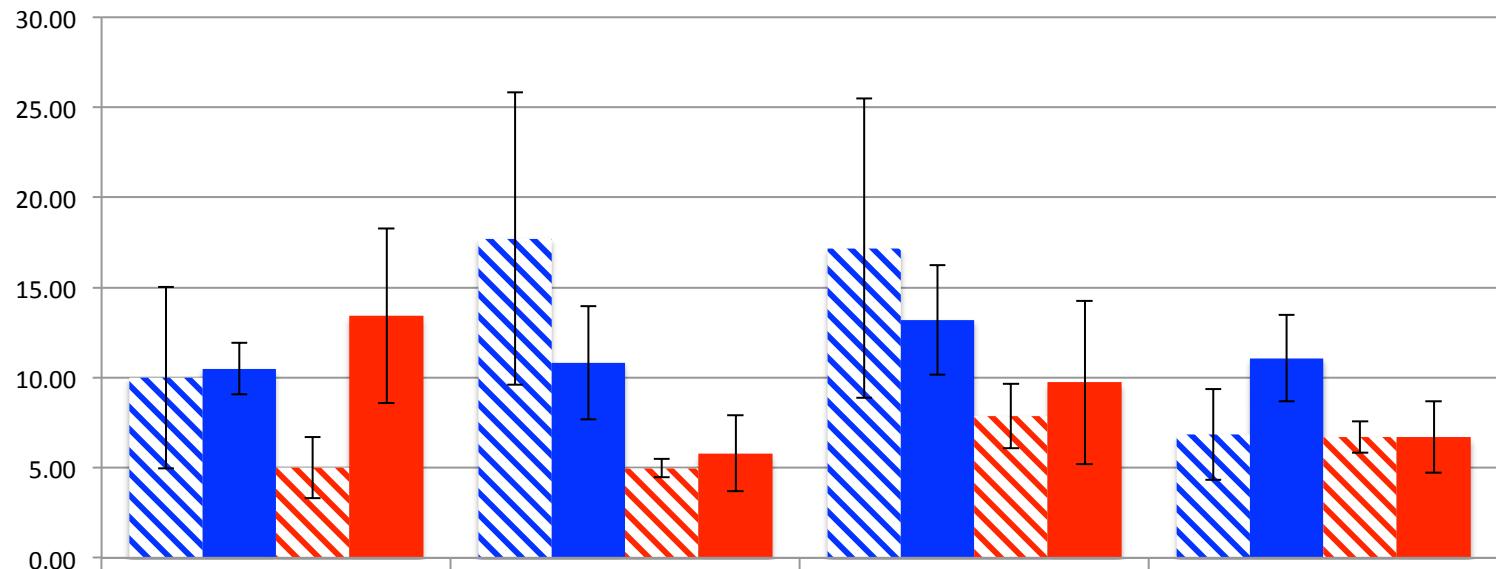
Non-Cooperative SS Alerts



- There was no significant effect of Display on Initial Response Time for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average of **6.84 seconds** to initiate an edit in response to a Non-Cooperative SS alert



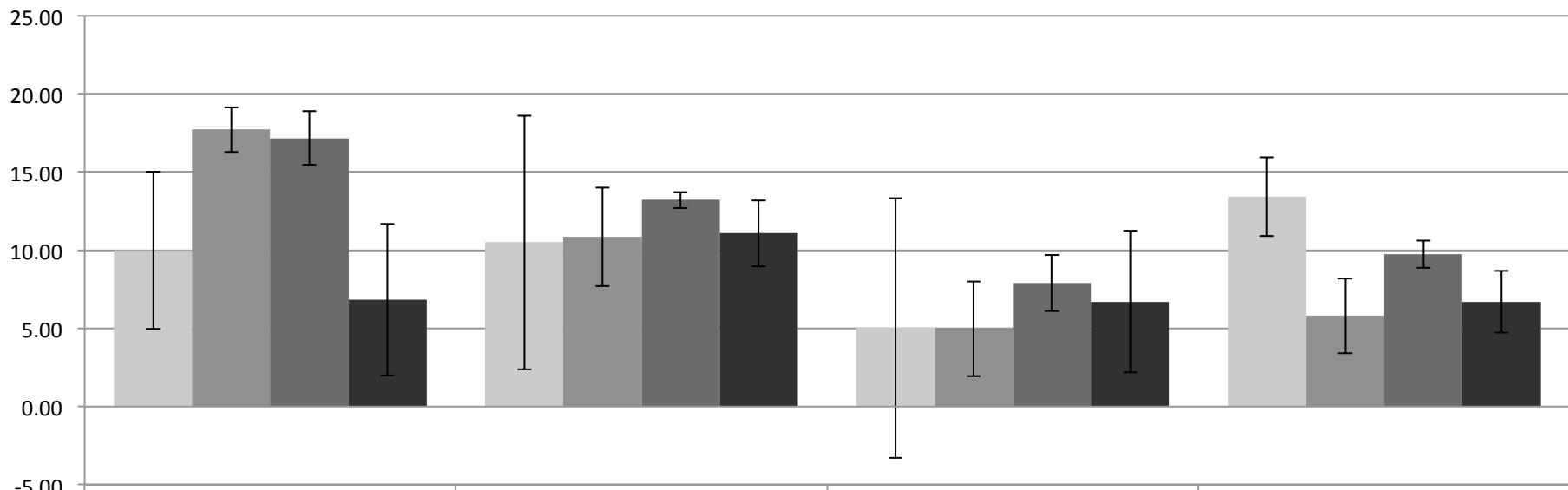
Initial Response Time



Cooperative/Predictive	10.00
Cooperative/Non-Predictive	10.50
Non-Cooperative/Predictive	5.02
Non-Cooperative/Non-Predictive	13.43



Initial Response Time

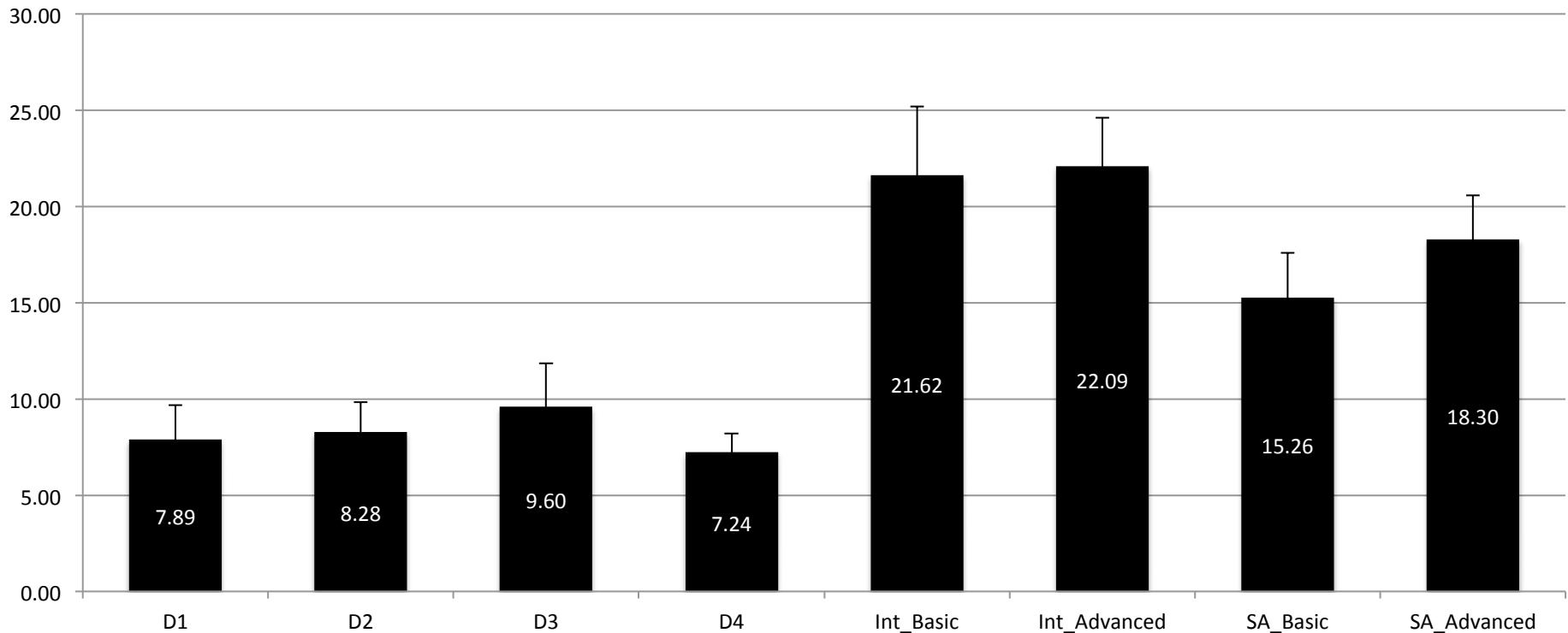


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	10.00	10.50	5.02	13.43
D2	17.71	10.83	4.98	5.81
D3	17.17	13.20	7.88	9.73
D4	6.83	11.07	6.69	6.70



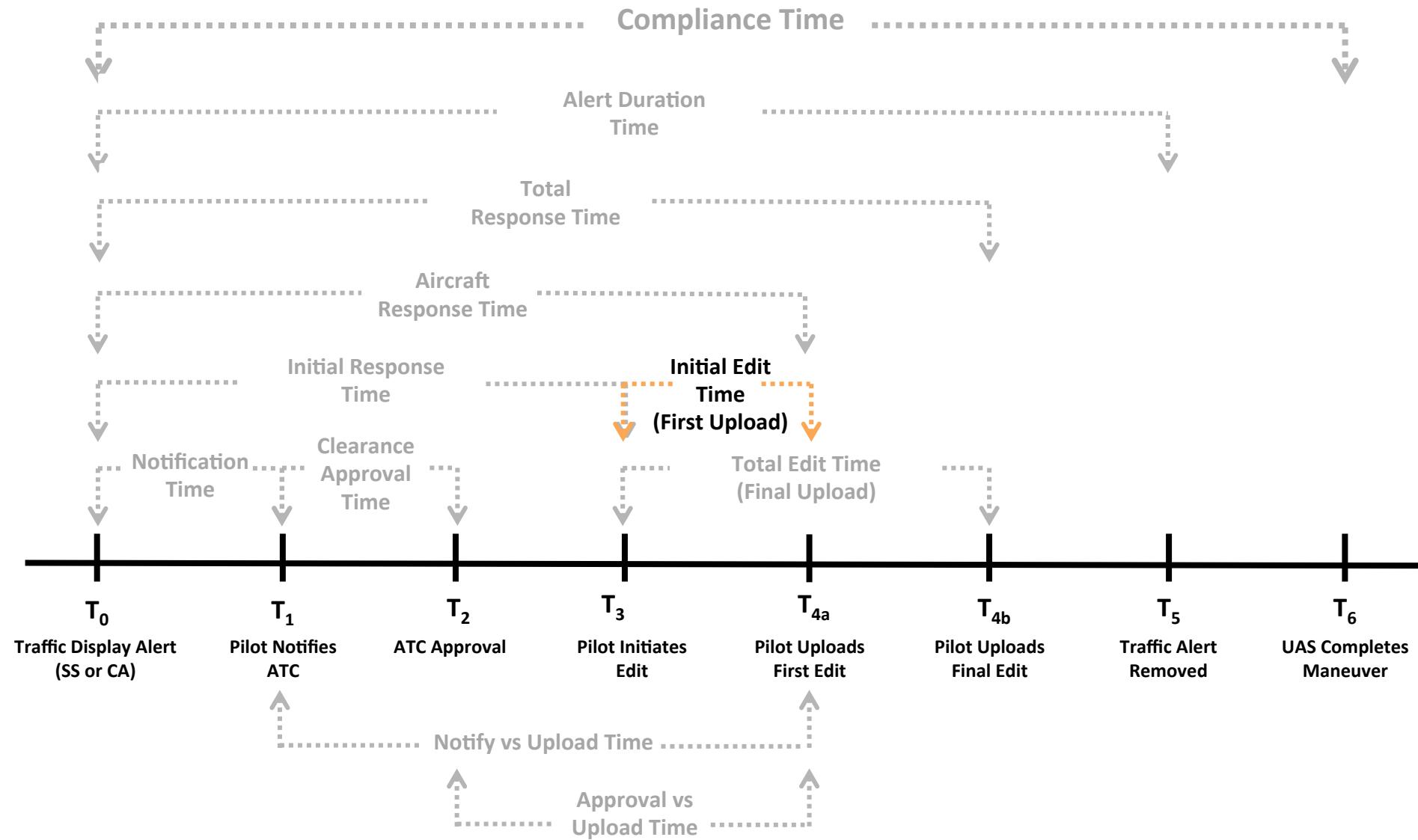
Initial Response Time

IHTL and PT4 Display Comparison



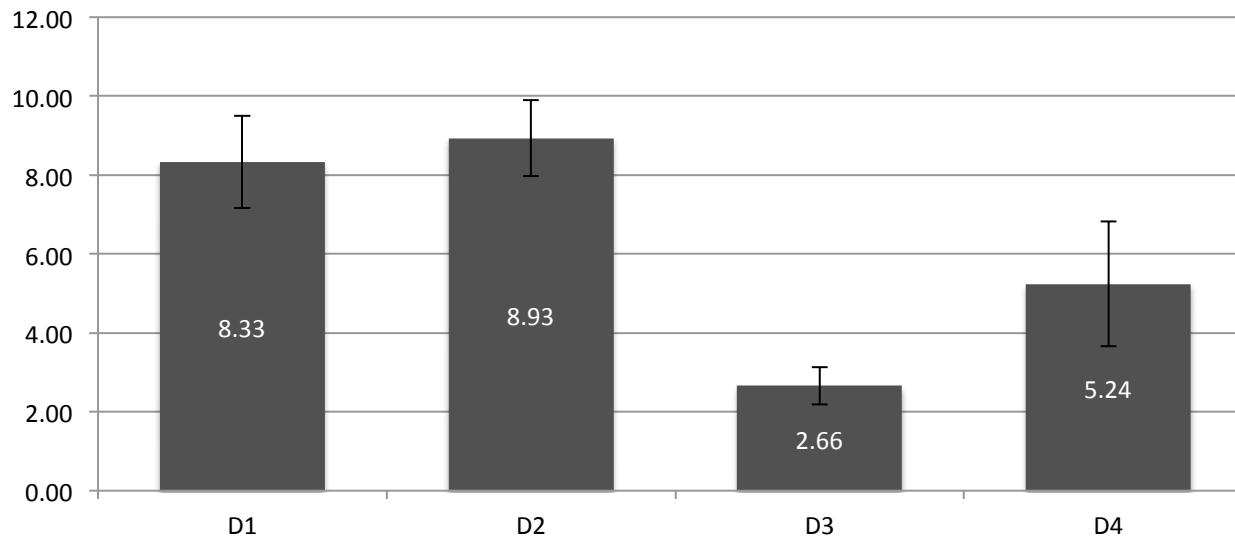


Stages of Pilot DAA Task





Initial Edit Time



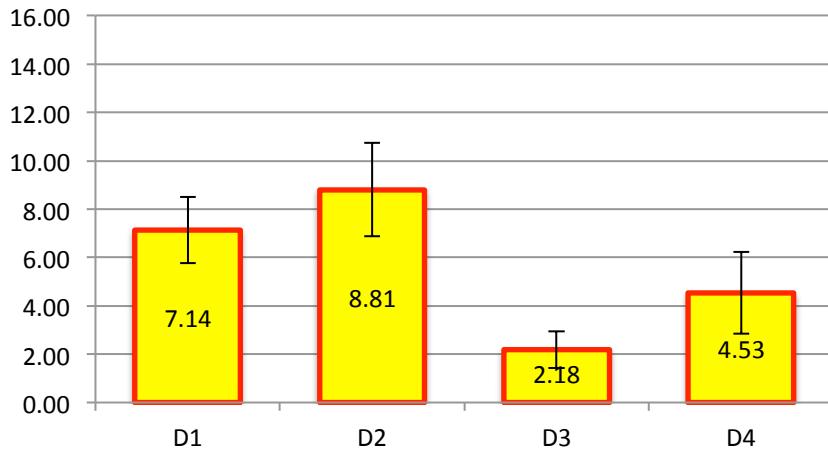
- There was a significant effect of Display on Initial Edit Time for all SS alerts, $p < .01$
 - D3 was significantly faster than D1 and D2
- Pilots took an average of **6.29 seconds** to complete their first edit in response to SS alerts



Initial Edit Time

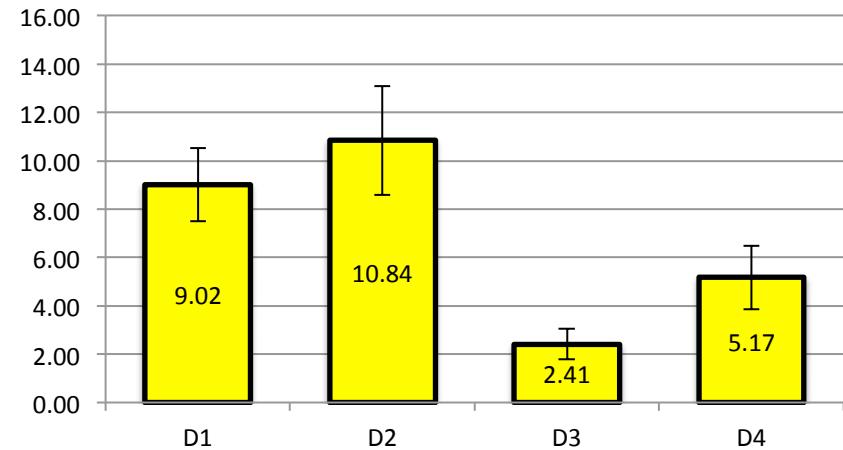


Predictive SS Alerts



- There was a significant effect of Display on Initial Edit Time for Predictive SS alerts, $p < .05$
 - D3 was significantly faster than D1
- Pilots took an average of **5.67 seconds** to complete their first edit in response to Predictive SS alerts

Non-Predictive SS Alerts

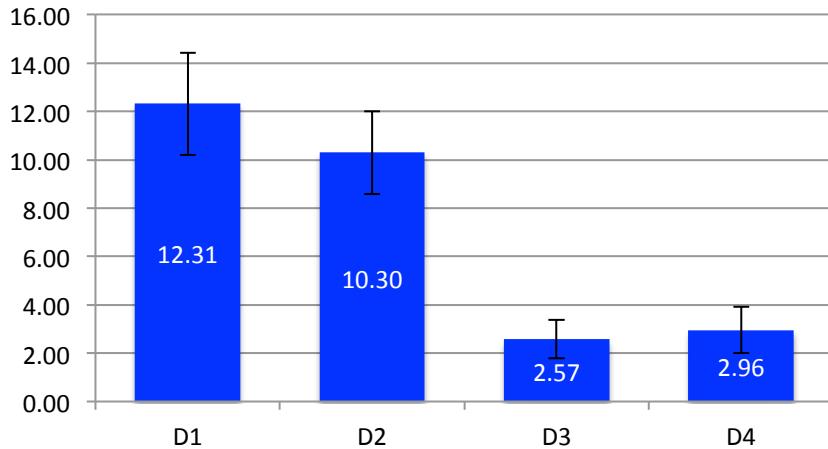


- There was a significant effect of Display on Initial Edit Time for Non-Predictive SS alerts, $p < .05$
 - D3 was significantly faster than D1 and D2
- Pilots took an average of **6.86 seconds** to complete their first edit in response to Non-Predictive SS alert



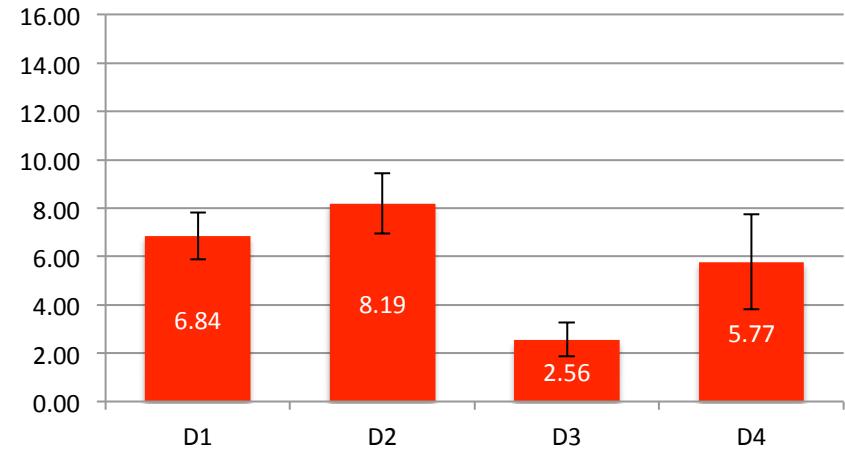
Initial Edit Time

Cooperative SS Alerts



- There was a significant effect of Display on Initial Edit Time for Cooperative SS alerts, $p < .01$
 - D3 and D4 were both significantly faster than D1 and D2
 - No difference between D1 and D2
 - No difference between D3 and D4
- Pilots took an average of **7.04 seconds** to complete their first edit in response to Cooperative SS alerts

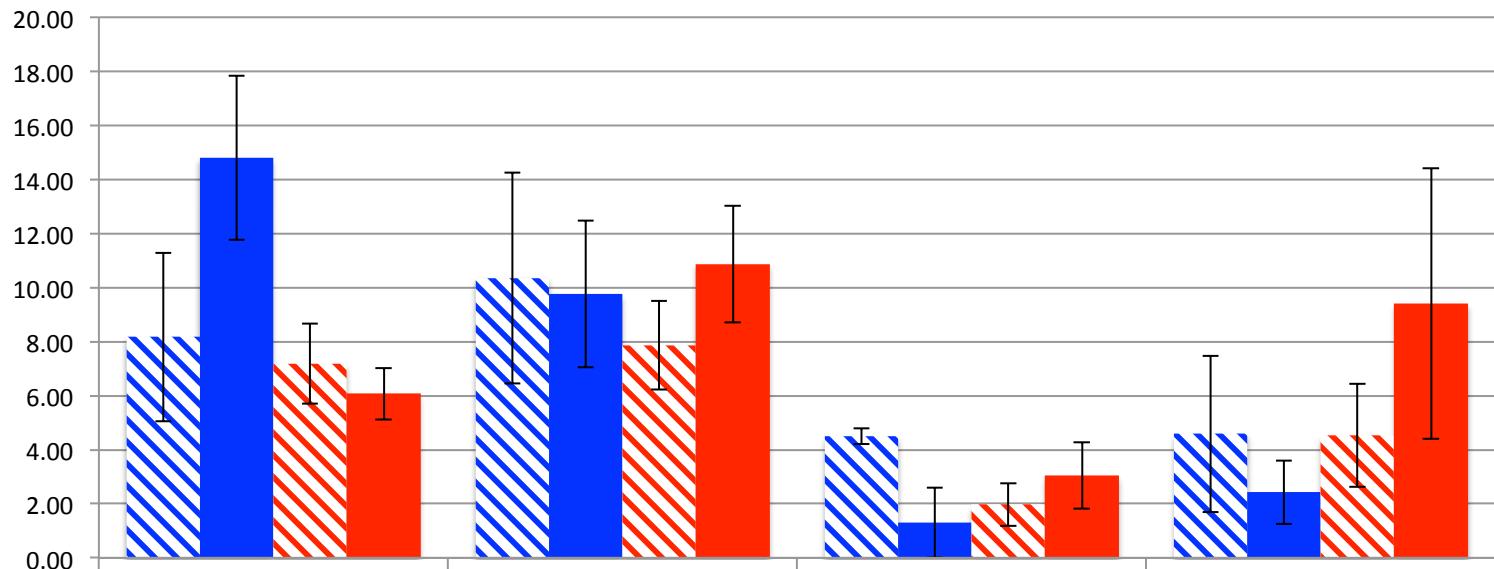
Non-Cooperative SS Alerts



- There was a near significant effect of Display on Initial Edit Time for Non-Cooperative Alerts, $p = .056$
- Pilots took an average of **5.84 seconds** to complete their first edit in response to Non-Cooperative alerts



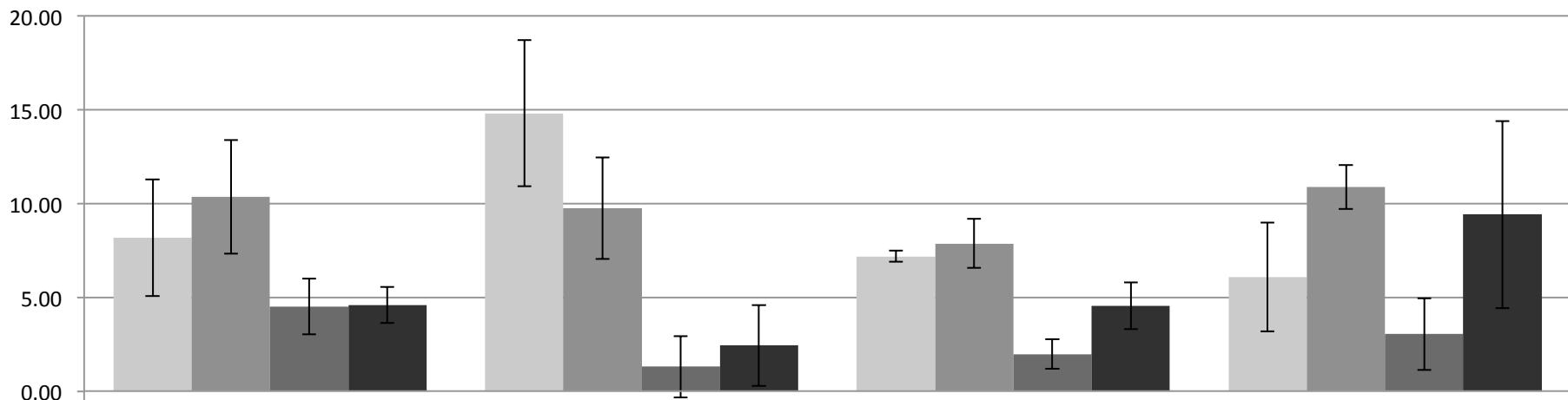
Initial Edit Time



Cooperative/Predictive	8.17
Cooperative/Non-Predictive	14.80
Non-Cooperative/Predictive	7.18
Non-Cooperative/Non-Predictive	6.07



Initial Edit Time

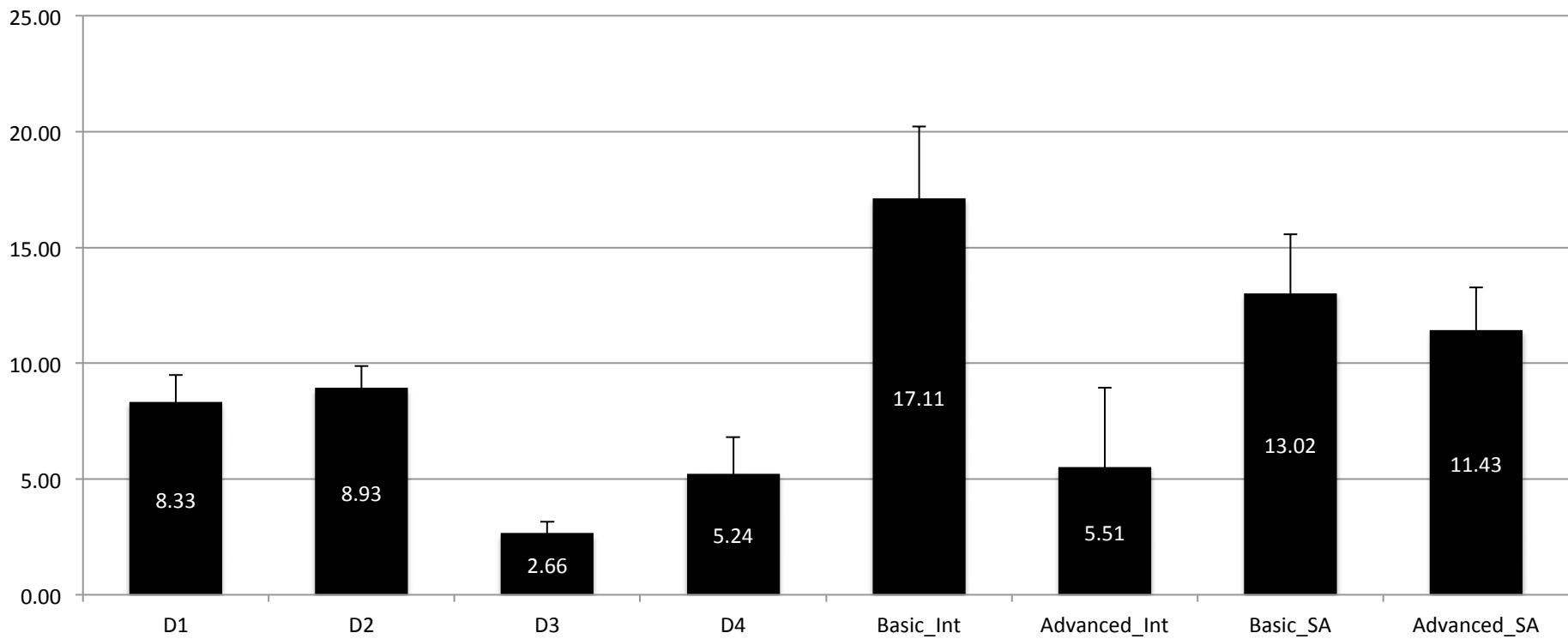


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	8.17	14.80	7.18	6.07
D2	10.36	9.75	7.86	10.86
D3	4.50	1.30	1.97	3.04
D4	4.58	2.43	4.54	9.40



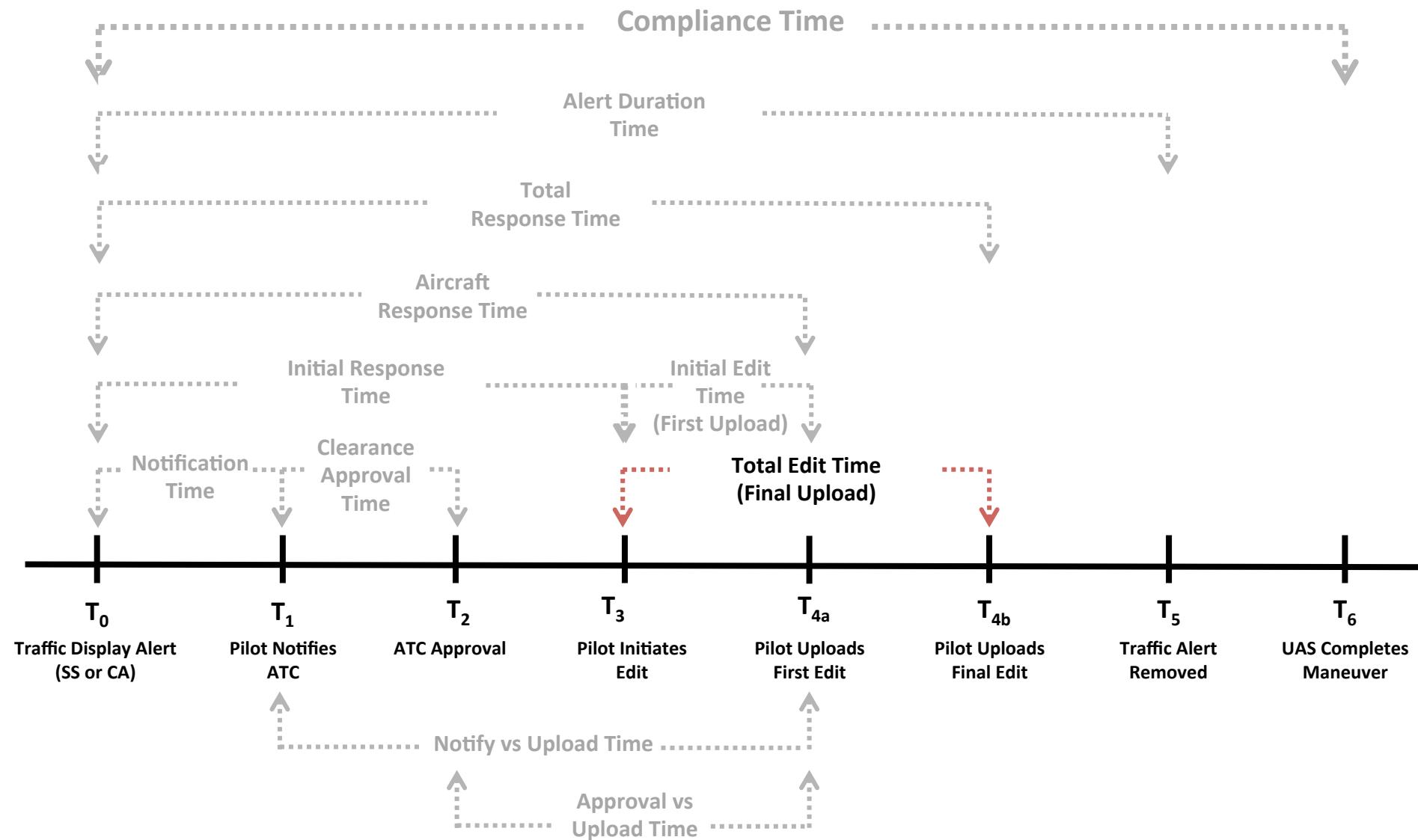
Initial Edit Time

IHTML and PT4 Display Comparison



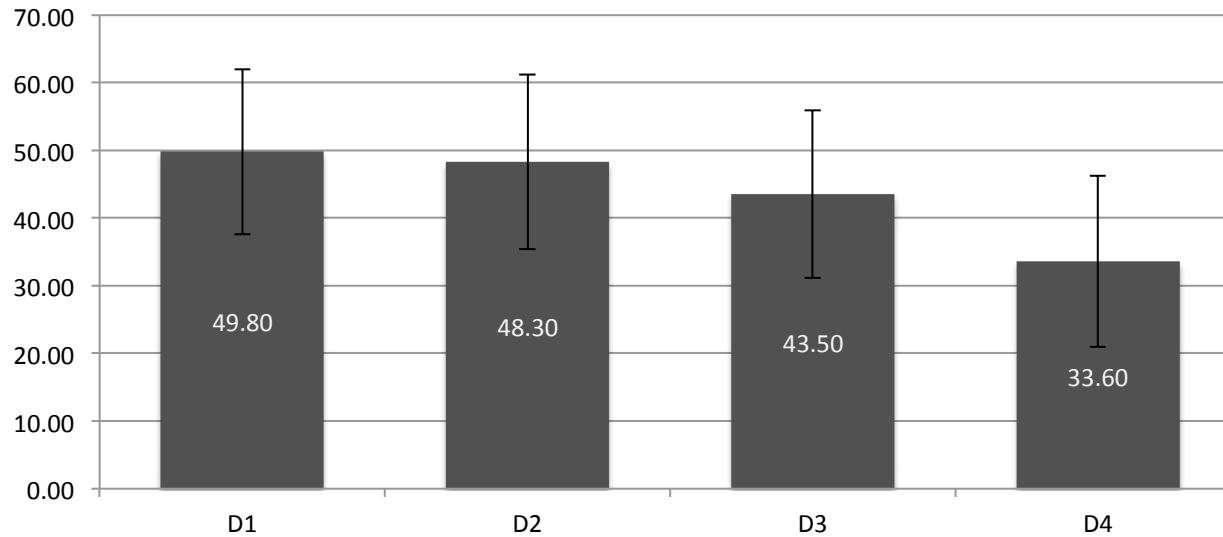


Stages of Pilot DAA Task





Total Edit Time

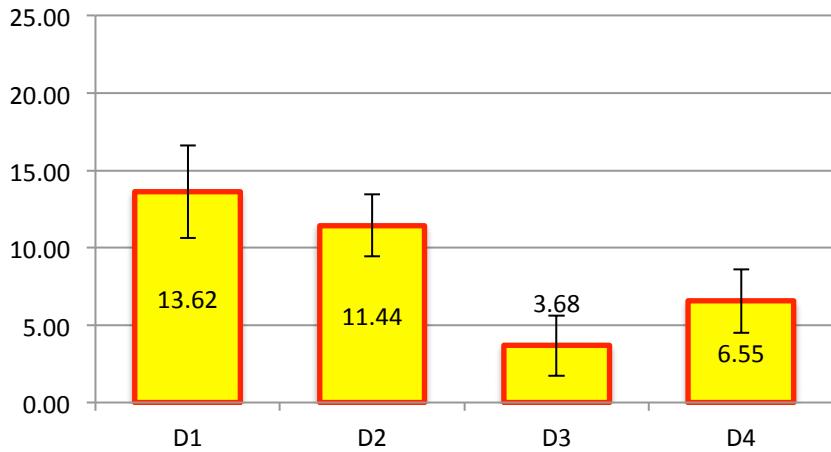


- There was a not significant effect of Display on Total Edit Time for all SS alerts, $p > .05$
- Pilots took an average of **9.83 seconds** to complete their final edit in response to SS alerts



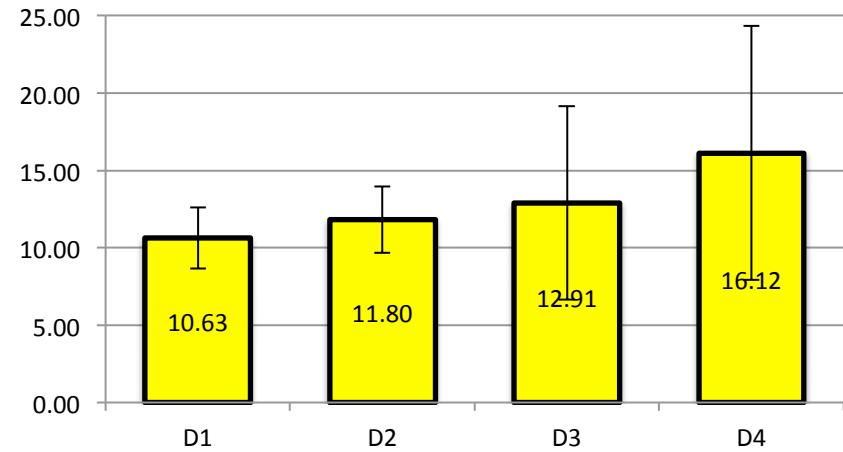
Total Edit Time

Predictive SS Alerts



- There was a significant effect of Display on Total Edit Time for Predictive alerts, $p < .05$
 - D3 was significantly faster than D2, but no different than the other two displays
- Pilots took an average of **8.83 seconds** to complete their final edit in response to Predictive SS alerts

Non-Predictive SS Alerts

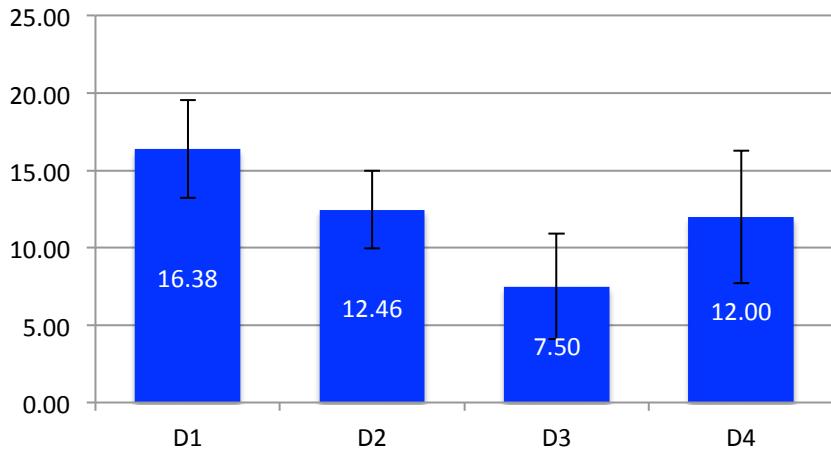


- There was no significant main effect of Display on Total Edit Time for Non-Predictive alerts, $p > .05$
- Pilots took an average of **12.862 seconds** to complete their final edit in response to Non-Predictive SS alerts



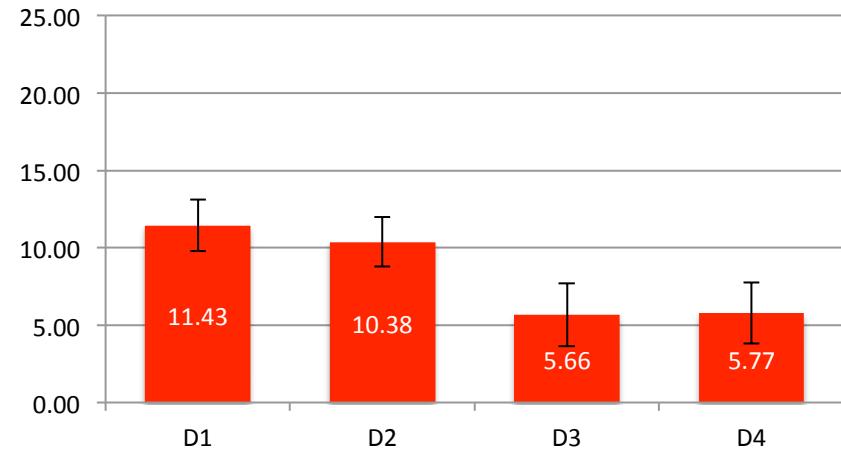
Total Edit Time

Cooperative SS Alerts



- There was no significant effect of Display on Total Edit Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **12.08 seconds** to complete their final edit in response to Cooperative SS alerts

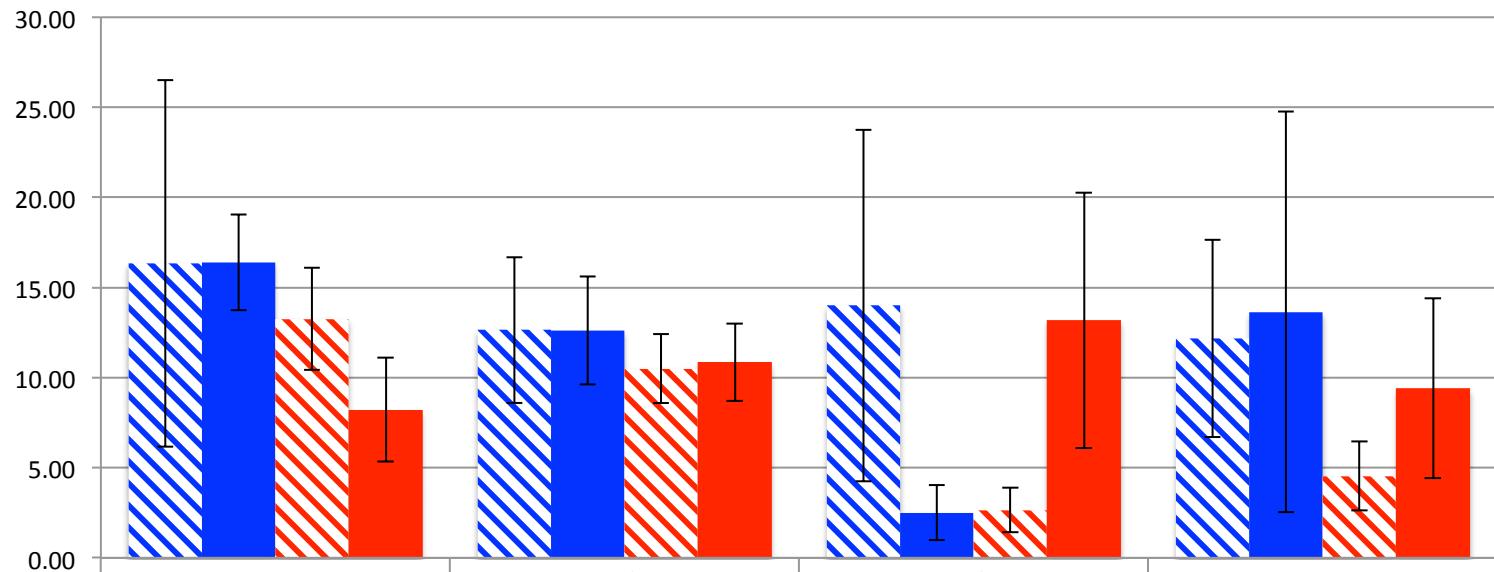
Non-Cooperative SS Alerts



- There was a near significant effect of Display on Total Edit Time for Non-Cooperative SS alerts, $p = .064$
- Pilots took an average of **8.31 seconds** to complete their final edit in response to Non-Cooperative alerts



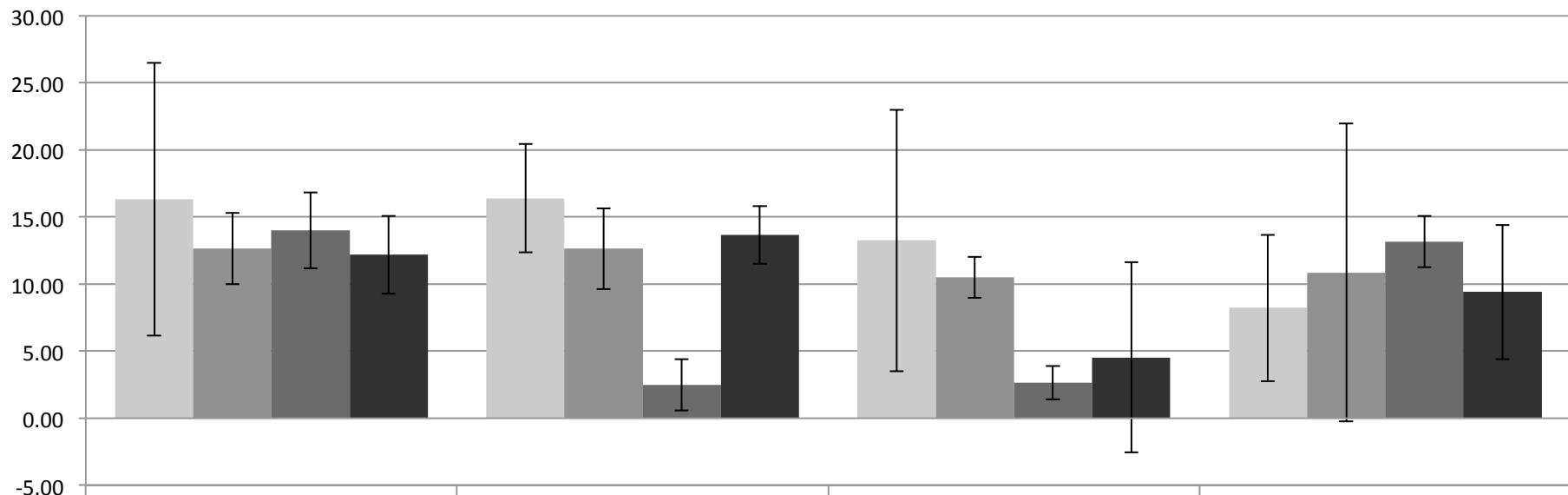
Total Edit Time



Cooperative/Predictive	16.33	12.64	14.00	12.17
Cooperative/Non-Predictive	16.40	12.63	2.50	13.64
Non-Cooperative/Predictive	13.26	10.50	2.64	4.54
Non-Cooperative/Non-Predictive	8.21	10.86	13.17	9.40



Total Edit Time

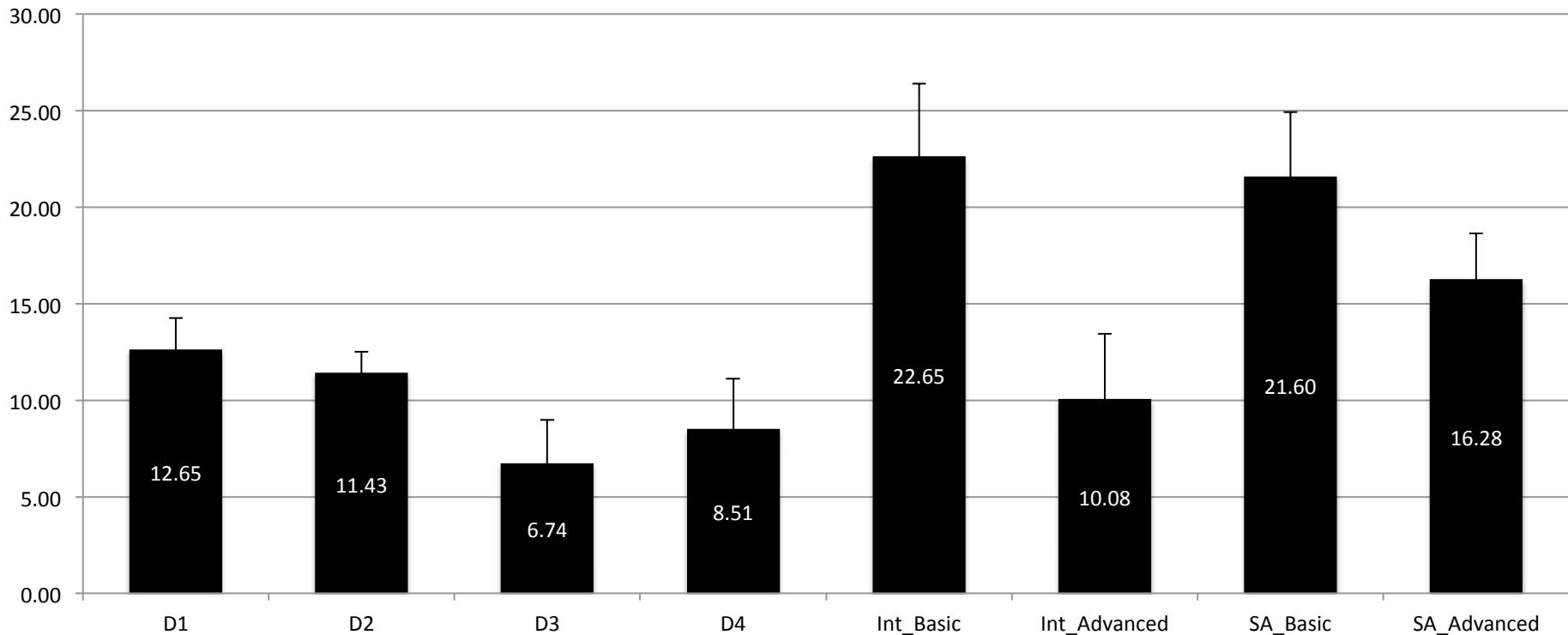


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	16.33	16.40	13.26	8.21
D2	12.64	12.63	10.50	10.86
D3	14.00	2.50	2.64	13.17
D4	12.17	13.64	4.54	9.40



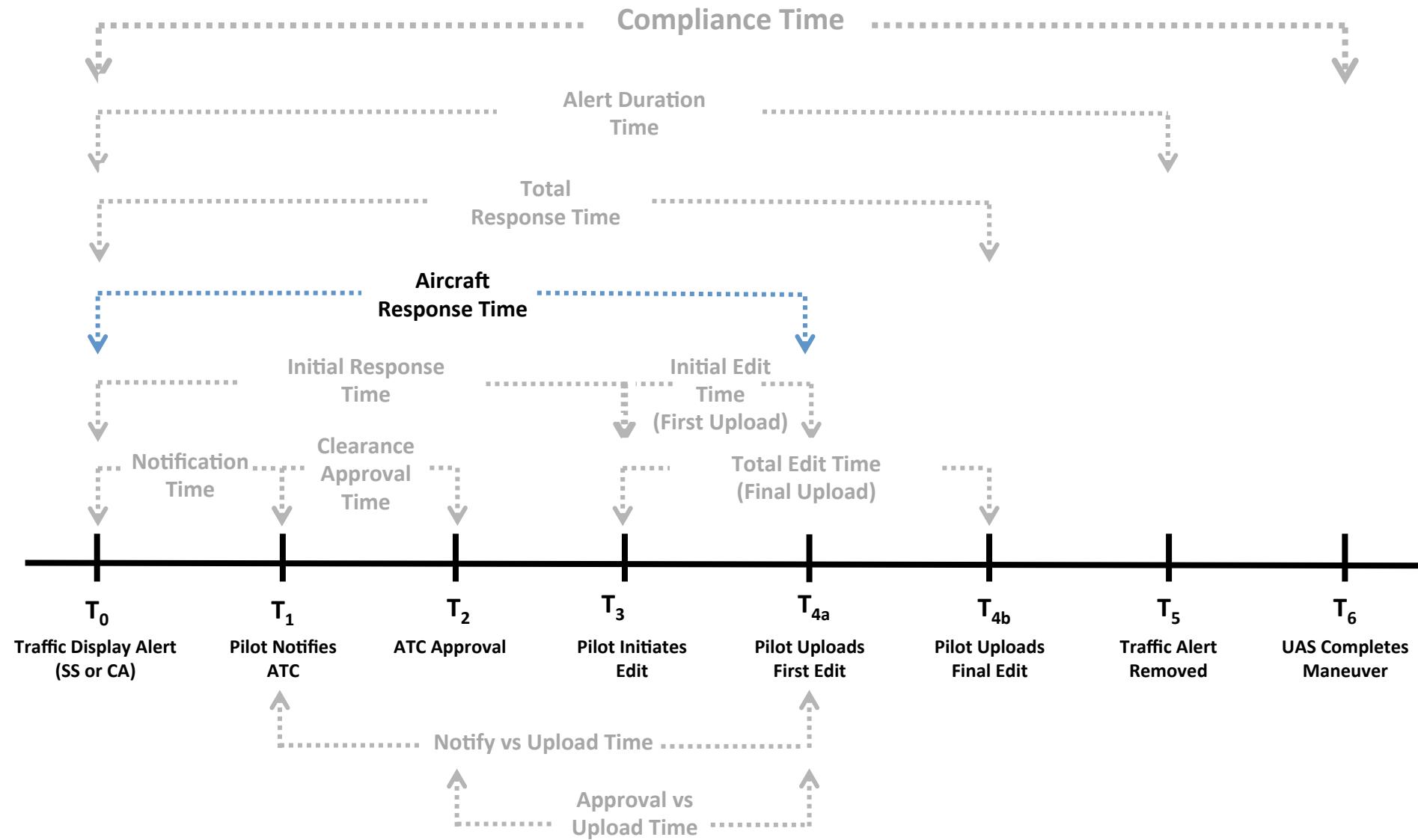
Total Edit Time

IHTML and PT4 Display Comparison



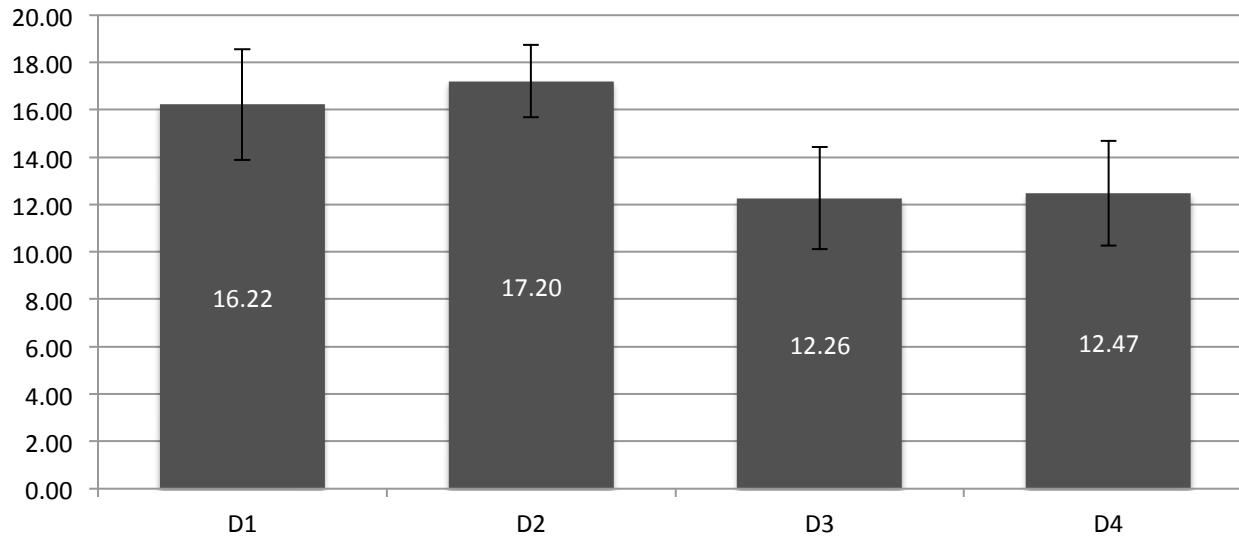


Stages of Pilot DAA Task





Aircraft Response Time

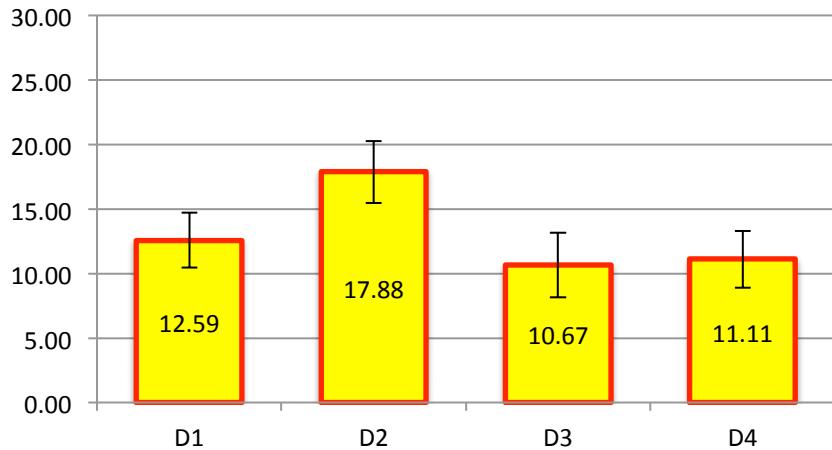


- There was a near significant effect of Display on Aircraft Response Time for all SS alerts, $p = .069$
- Pilots took an average of **14.54 seconds** to upload their first maneuver in response to SS alerts (from first alert appearance)



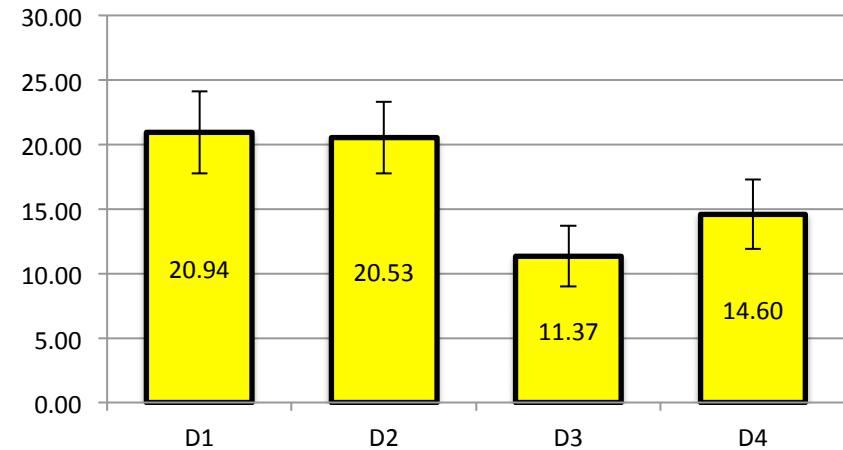
Aircraft Response Time

Predictive SS Alerts



- There was a near significant effect of Display on Aircraft Response Time for Predictive SS alerts, $p = .059$
- Pilots took an average of **13.06 seconds** to upload their first maneuver in response to Predictive SS alerts (from first alert appearance)

Non-Predictive SS Alerts

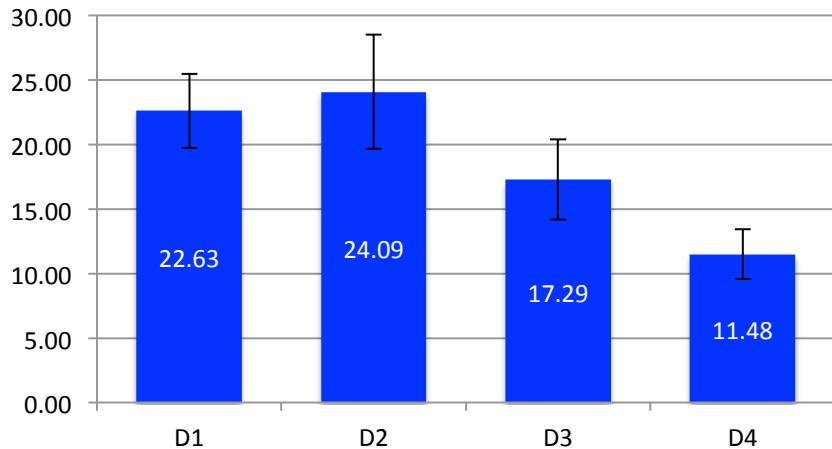


- There was a significant effect of Display on Aircraft Response Time for Non-Predictive SS alerts, $p < .05$
 - No differences between displays were significant
- Pilots took an average of **16.86 seconds** to upload their first maneuver in response to Non-Predictive SS alerts (from first alert appearance)



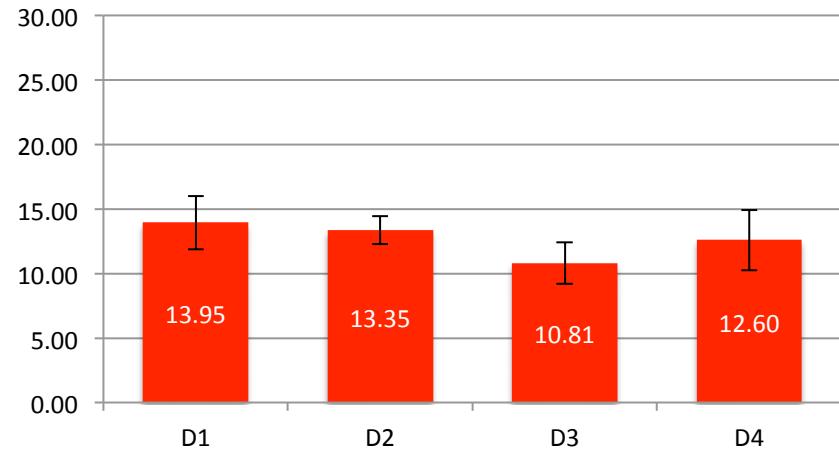
Aircraft Response Time

Cooperative SS Alerts



- There was a significant effect of Display on Aircraft Response Time for Cooperative SS alerts, $p < .01$
 - D4 was significantly faster than D1 and D2
- Pilots took an average of **18.87 seconds** to upload their first maneuver in response to Cooperative SS alerts (from first alert appearance)

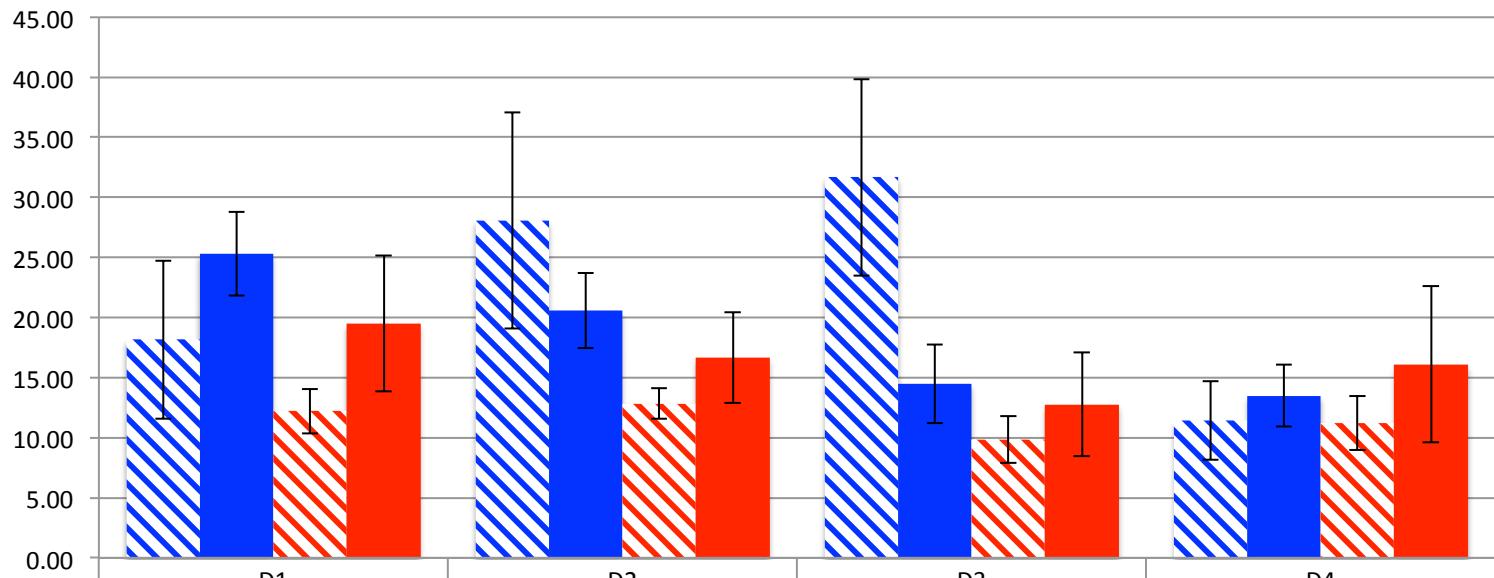
Non-Cooperative SS Alerts



- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average of **12.68 seconds** to upload their first maneuver in response to Non-Cooperative SS alerts (from first alert appearance)



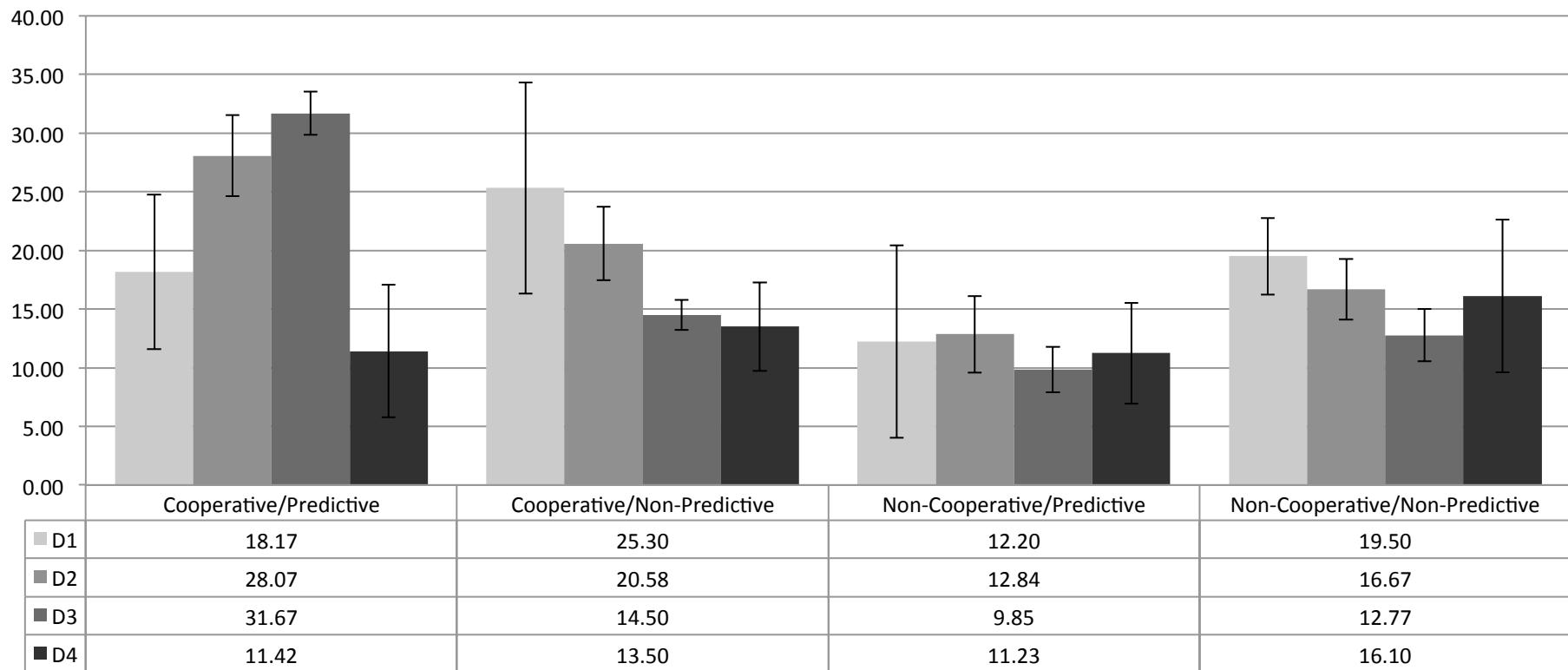
Aircraft Response Time



	D1	D2	D3	D4
Cooperative/Predictive	18.17	28.07	31.67	11.42
Cooperative/Non-Predictive	25.30	20.58	14.50	13.50
Non-Cooperative/Predictive	12.20	12.84	9.85	11.23
Non-Cooperative/Non-Predictive	19.50	16.67	12.77	16.10



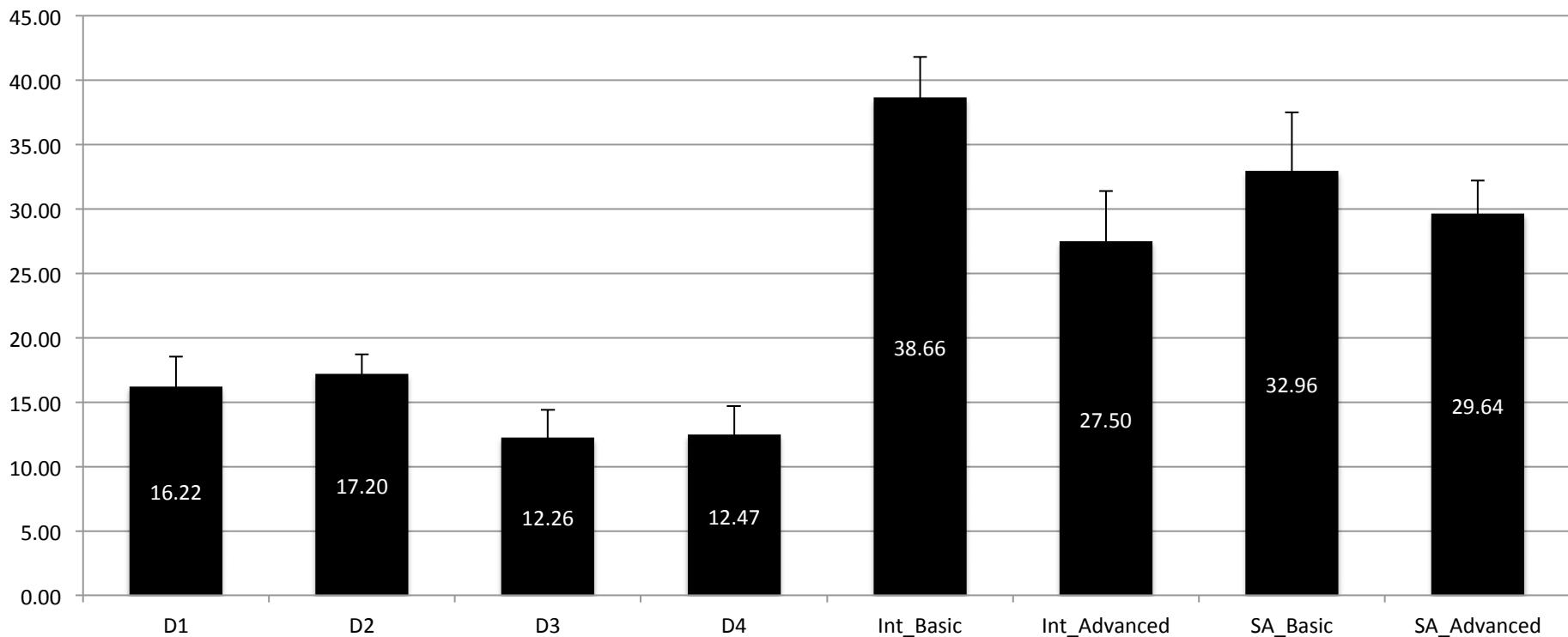
Aircraft Response Time





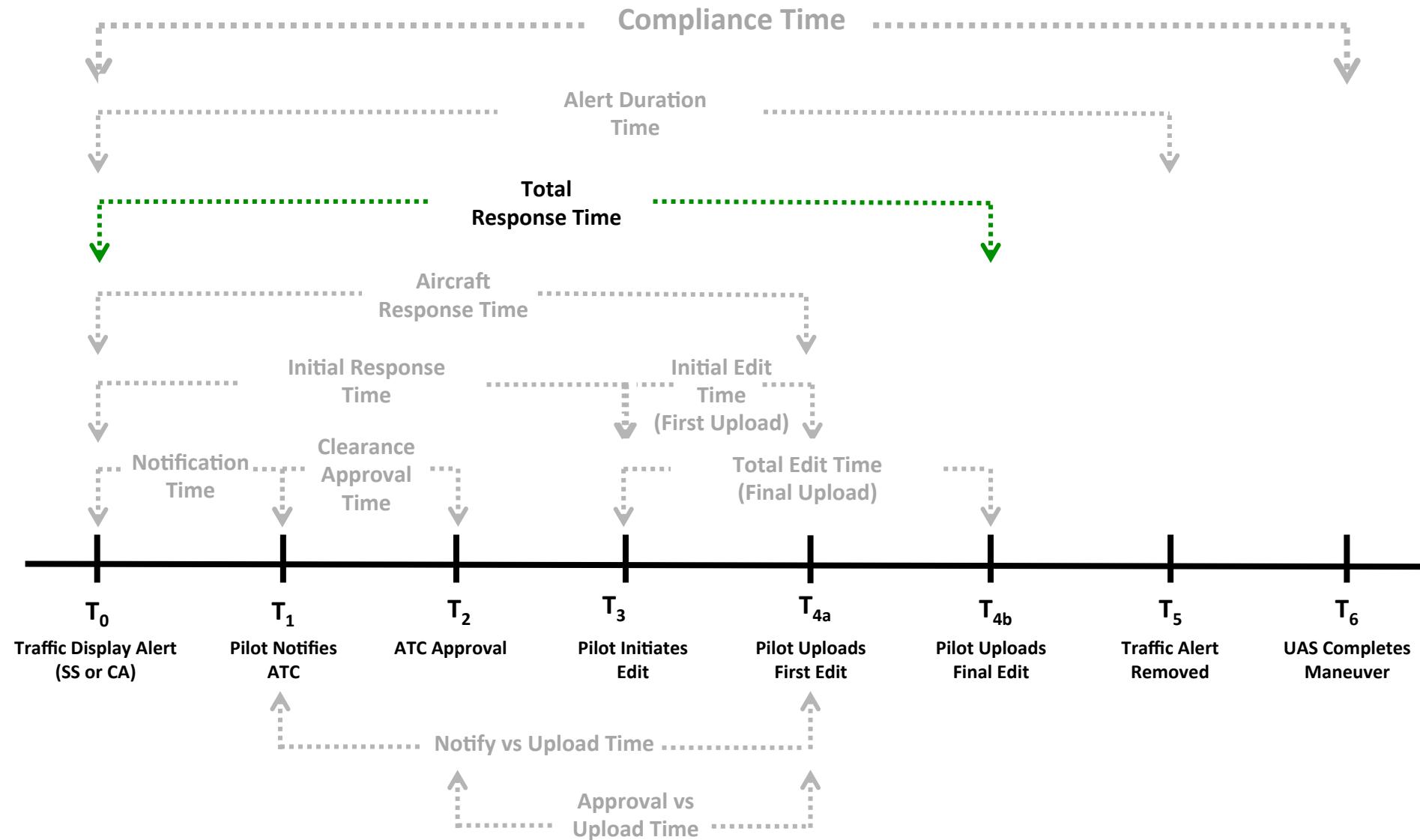
Aircraft Response Time

IHTL and PT4 Display Comparison



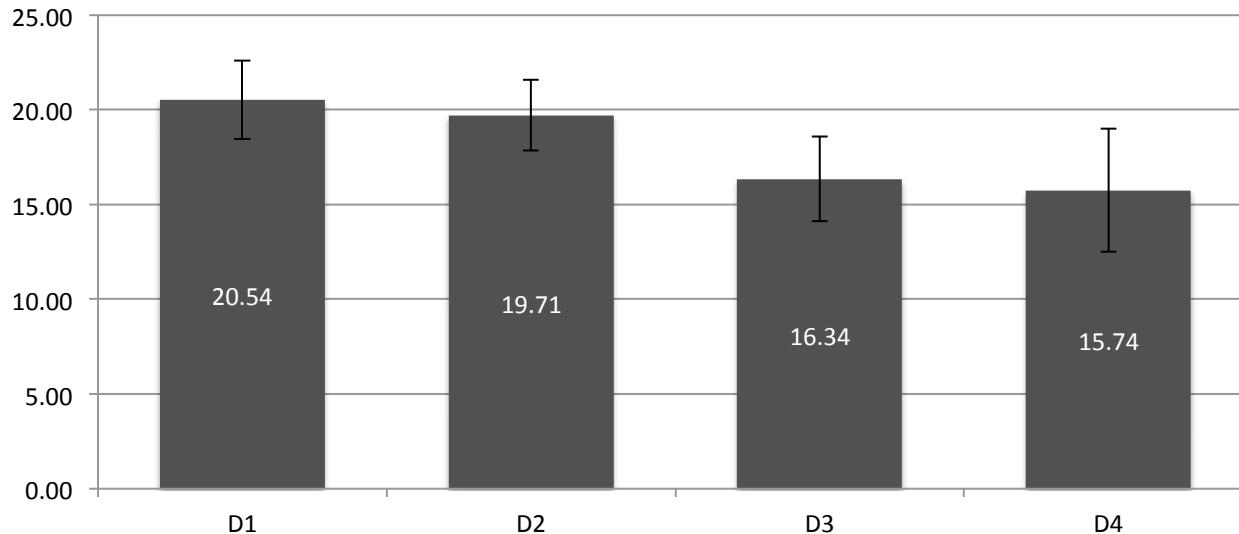


Stages of Pilot DAA Task





Total Response Time

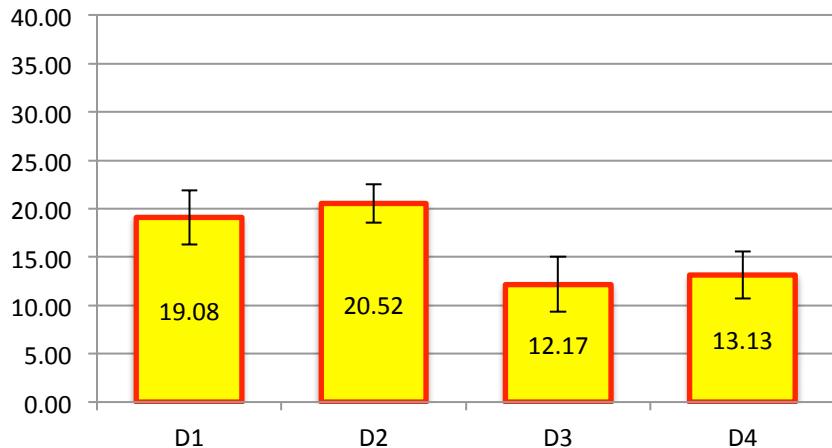


- There was not a significant effect of Information on Total Response Time for all SS alerts, $p > .05$
- Pilots took an average of **18.08 seconds** to complete their final edit in response to SS alerts (from first alert appearance)



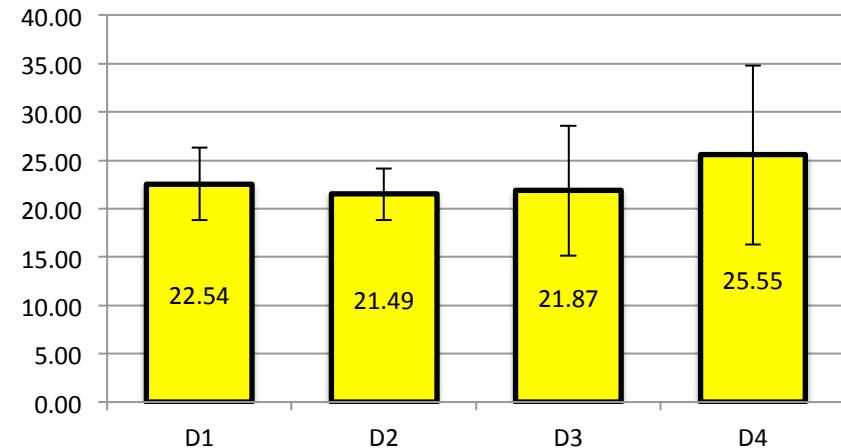
Total Response Time

Predictive SS Alerts



- There was a near significant effect of Display on Total Response Time for Predictive SS alerts, $p = .056$
- Pilots took an average of **16.22 seconds** to complete their final edit in response to Predictive SS alerts (from first alert appearance)

Non-Predictive SS Alerts

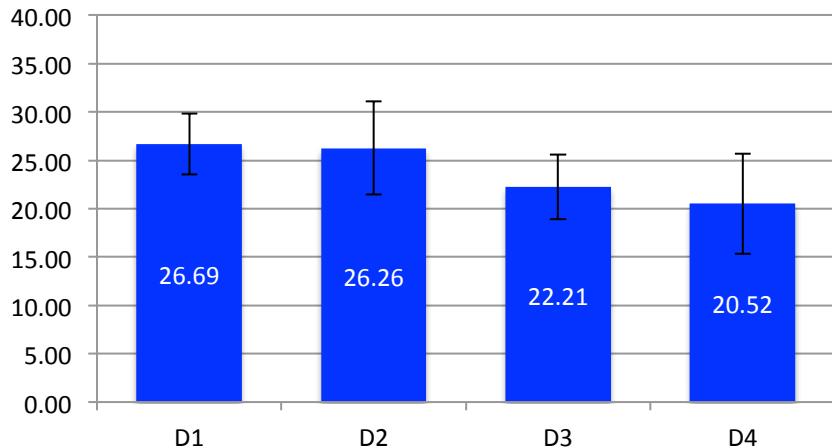


- There was no significant effect of Display on Total Response Time, $p > .05$
- Pilots took an average of **22.86 seconds** to complete their final edit in response to Non-Predictive SS alerts (from first alert appearance)



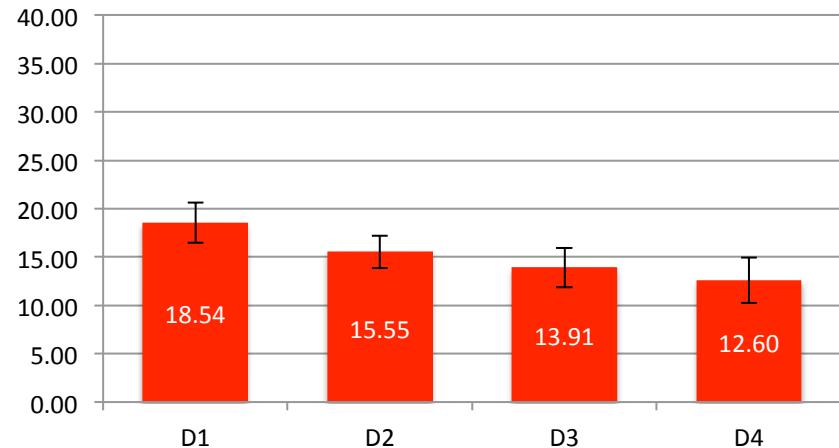
Total Response Time

Cooperative SS Alerts



- There was no significant effect of Information on Aircraft Response Time for Cooperative SS alerts, $p > .05$
- Pilots took an average of **23.92 seconds** to complete their final edit in response to Cooperative SS alerts (from first alert appearance)

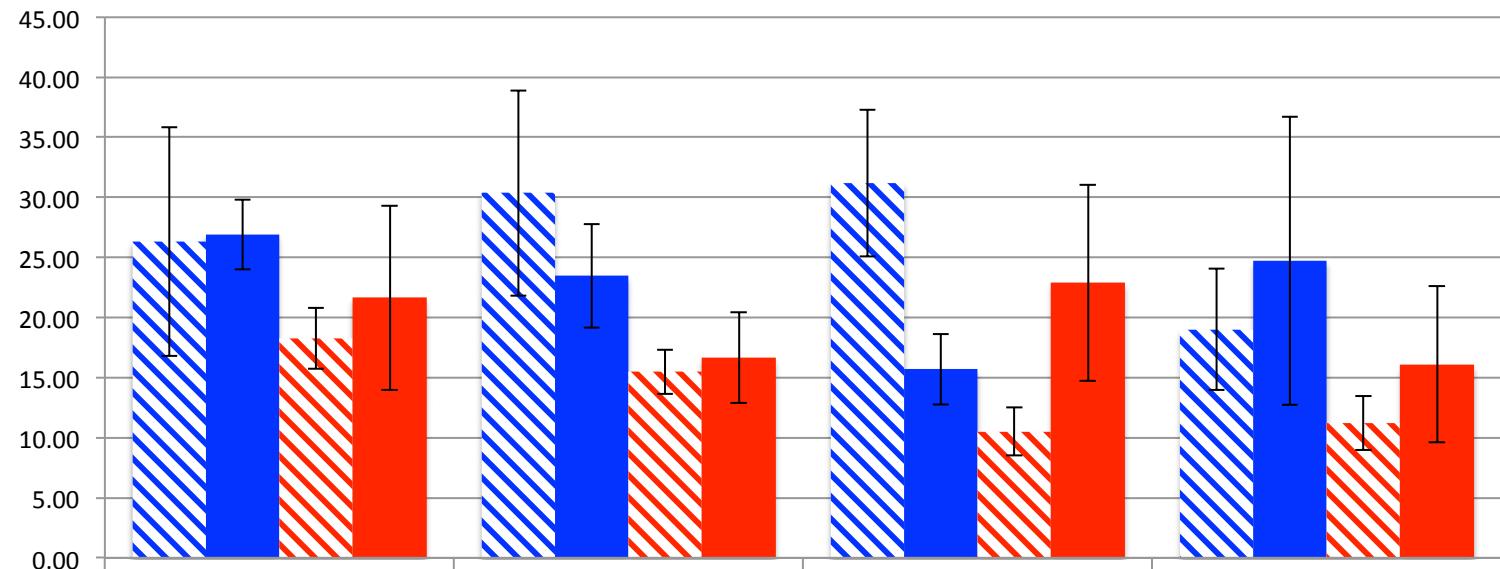
Non-Cooperative SS Alerts



- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average of **15.15 seconds** to complete their final edit in response to Non-Cooperative SS alerts (from first alert appearance)



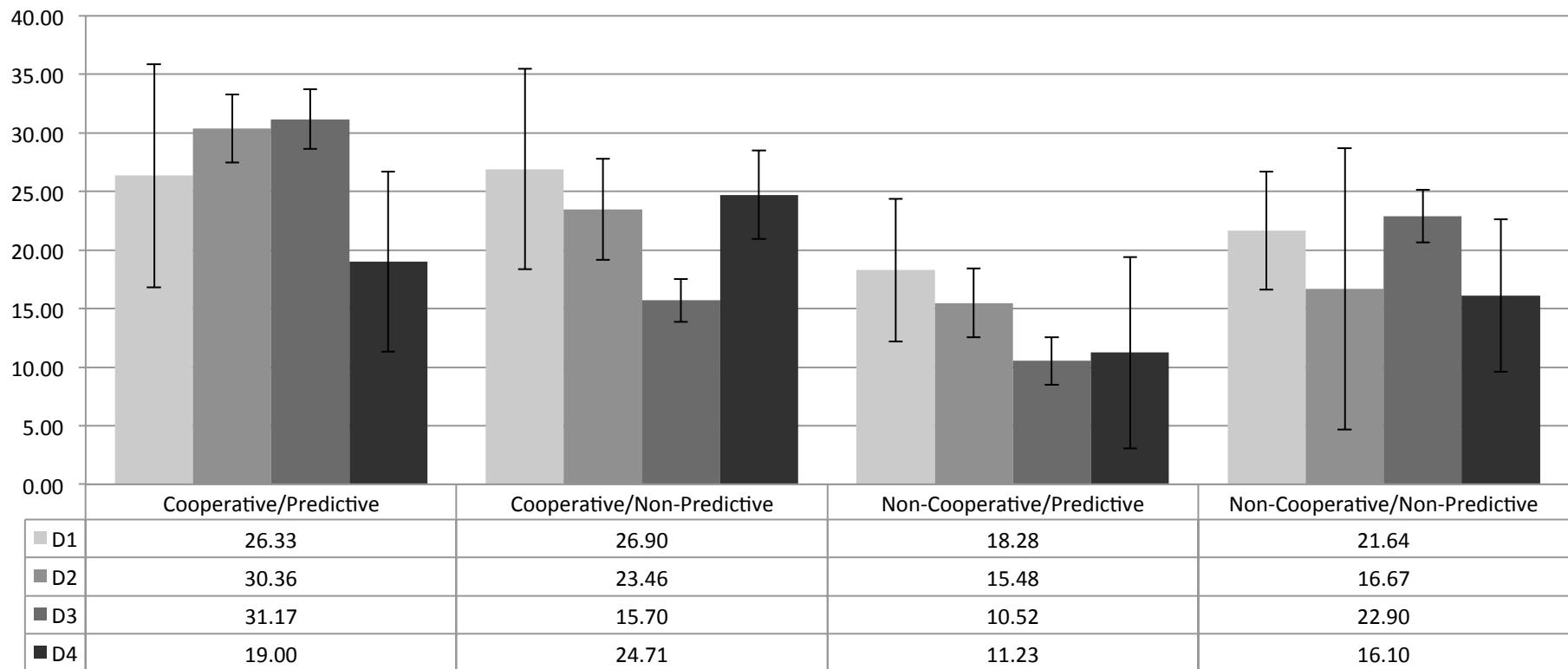
Total Response Time



Cooperative/Predictive	26.33
Cooperative/Non-Predictive	26.90
Non-Cooperative/Predictive	18.28
Non-Cooperative/Non-Predictive	21.64



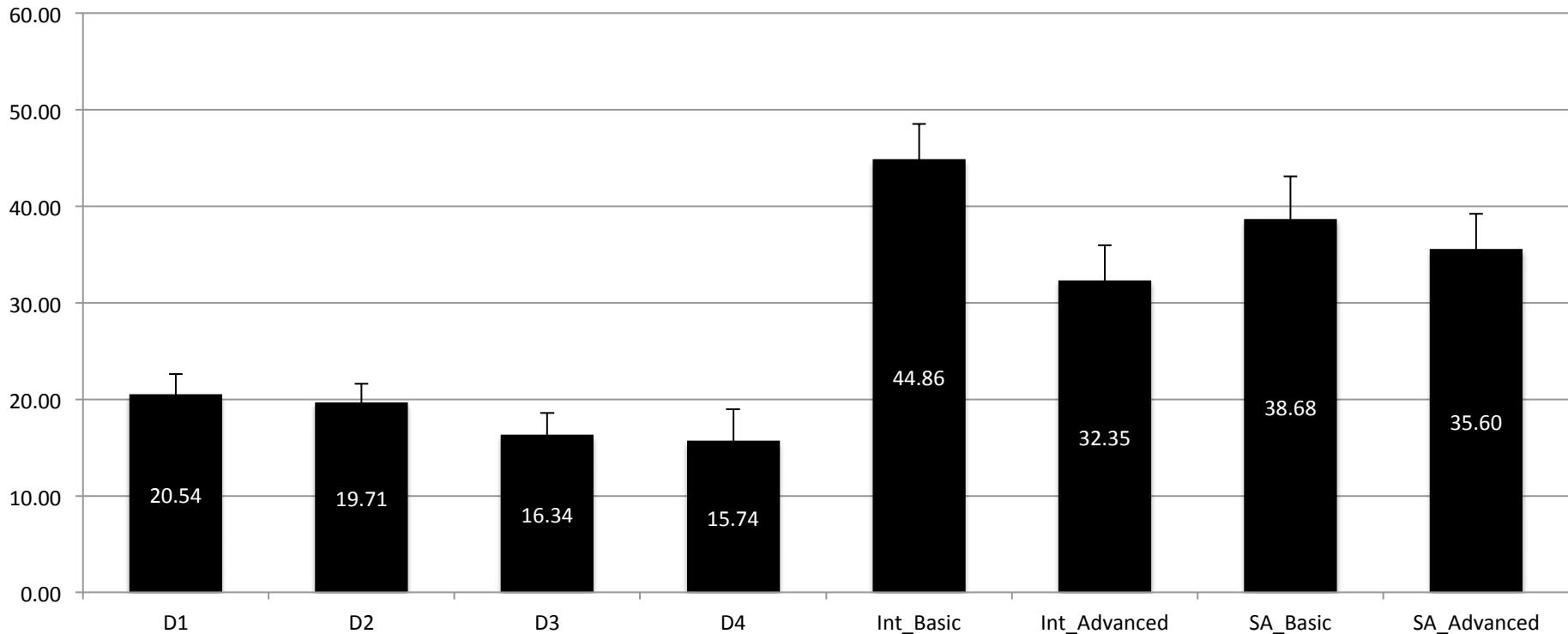
Total Response Time





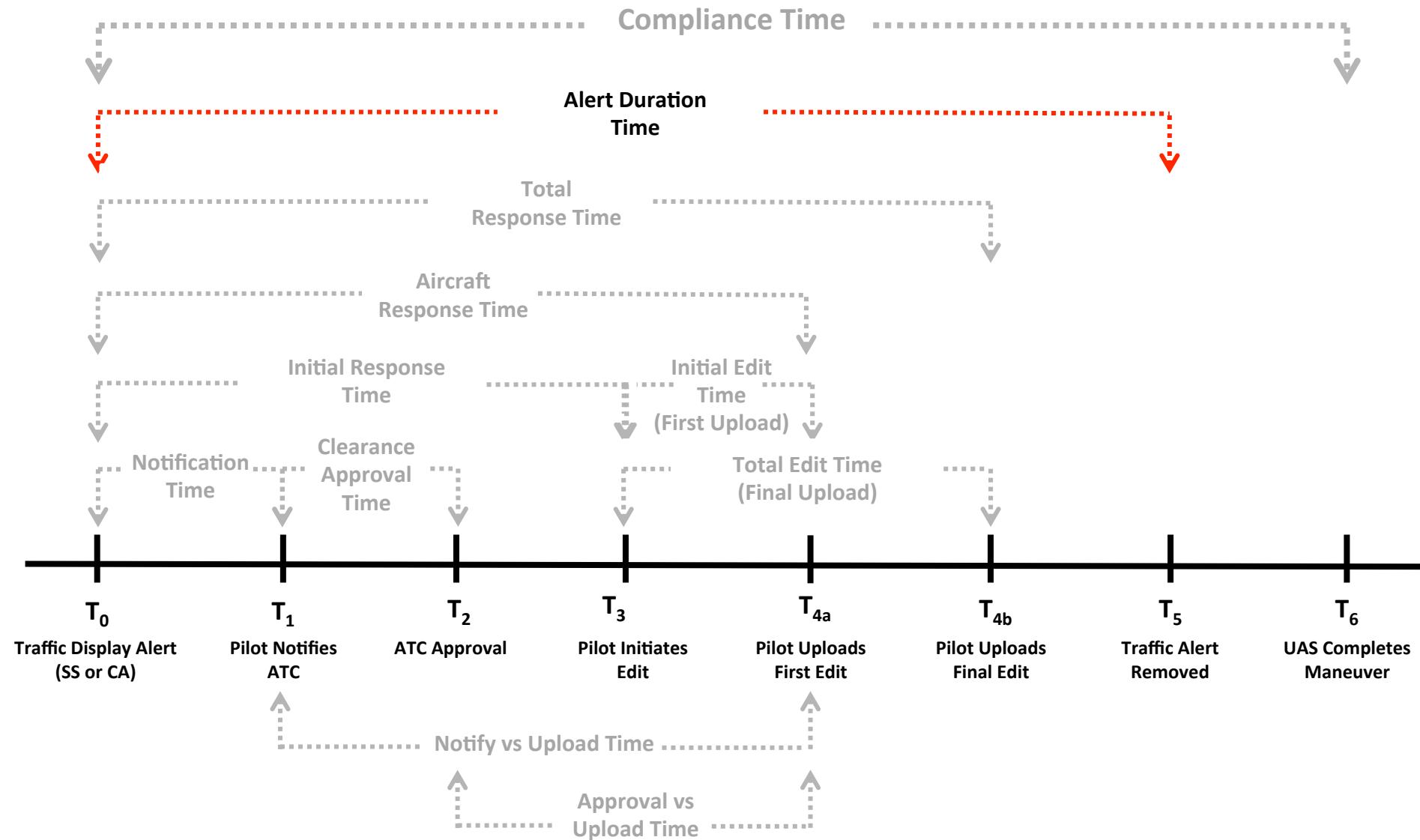
Total Response Time

IHTL and PT4 Display Comparison



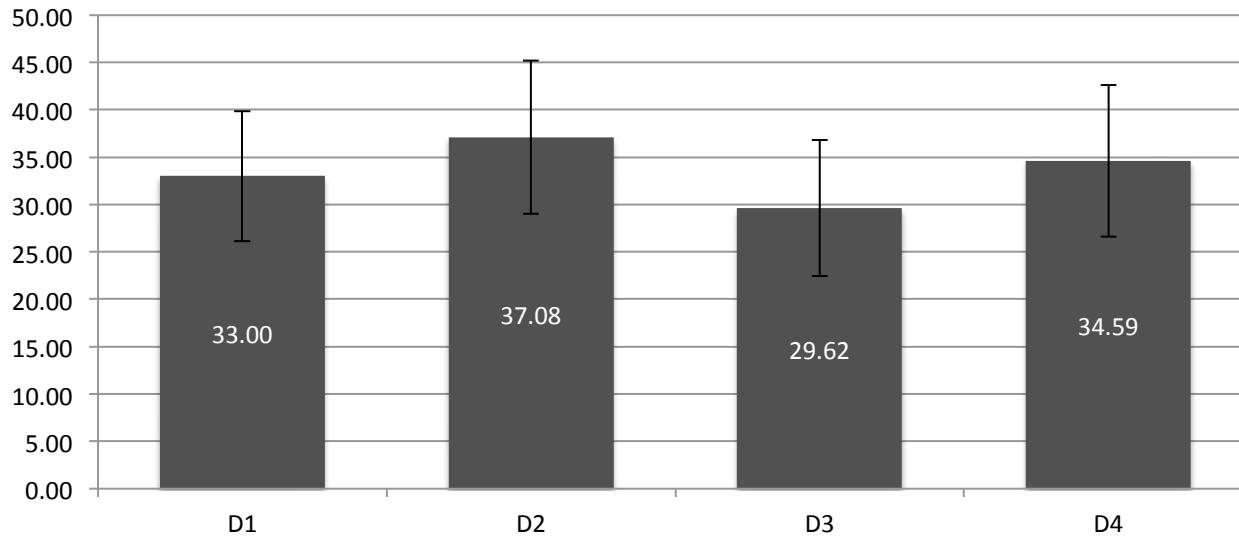


Stages of Pilot DAA Task





Alert Duration Time

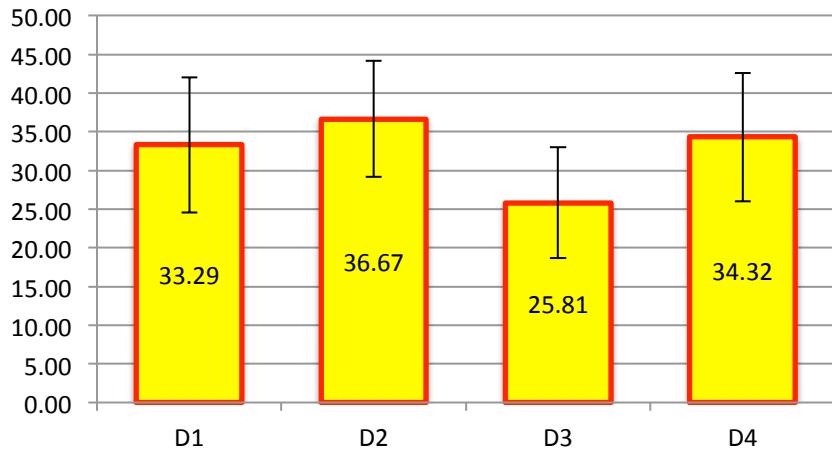


- There was no significant effect of Display on Alert Duration Time for all SS alerts, $p > .05$
- Pilots had an average duration of **33.58 seconds** for all Predictive SS alerts



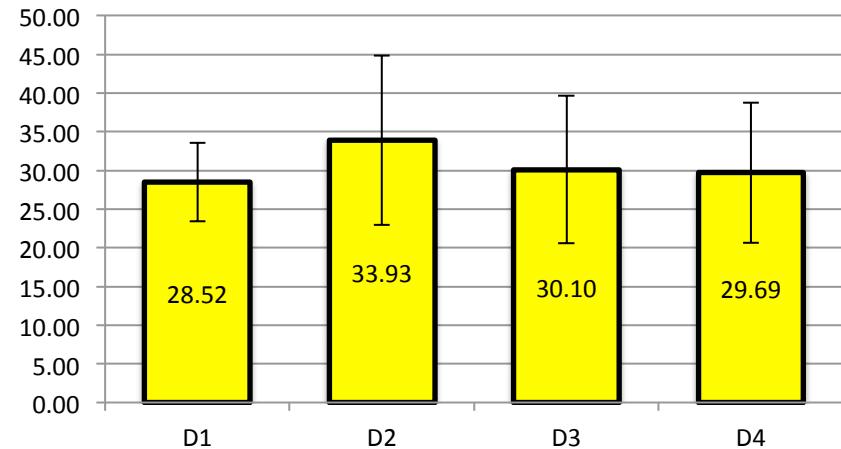
Alert Duration Time

Predictive SS Alerts



- There was no significant effect of Display on Alert Duration Time for Predictive SS alerts, $p > .05$
- Pilots had an average duration of **32.52 seconds** for all Predictive SS alerts

Non-Predictive SS Alerts

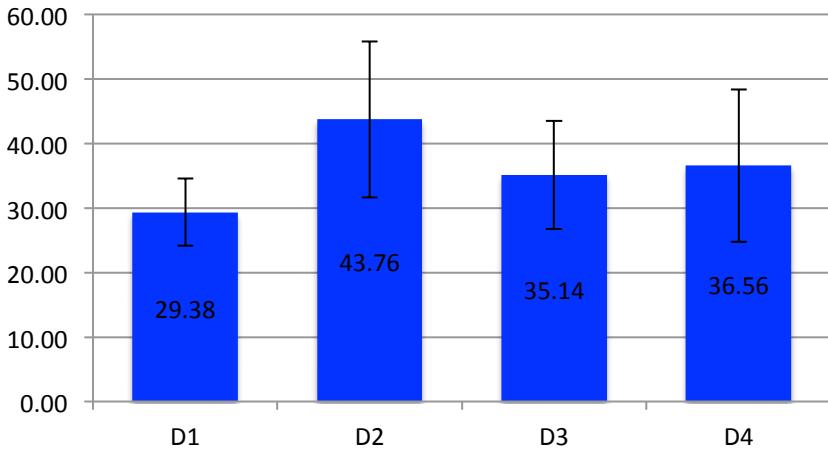


- There was no significant effect of Display on Alert Duration Time for Non-Predictive SS alerts, $p > .05$
- Pilots had an average duration of **30.56 seconds** for all Non-Predictive SS alerts



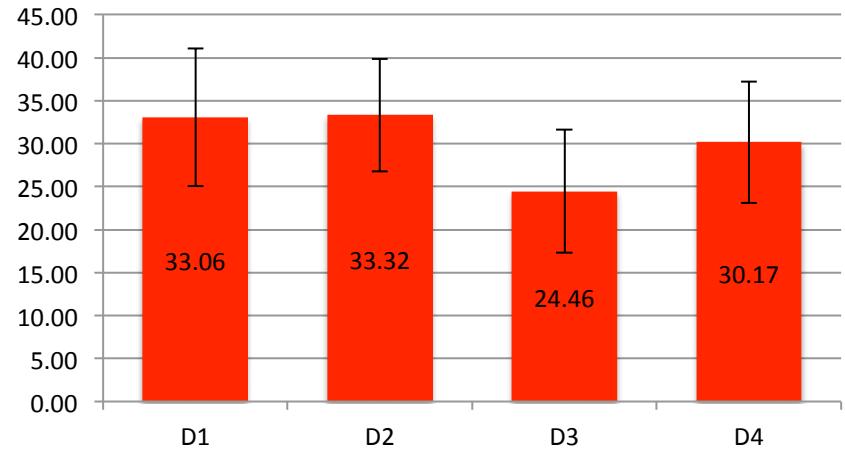
Alert Duration Time

Cooperative SS Alerts



- There was no significant effect of Display on Alert Duration Time for Cooperative SS alerts, $p > .05$
- Pilots had an average duration of **36.21 seconds** for all Cooperative SS alerts

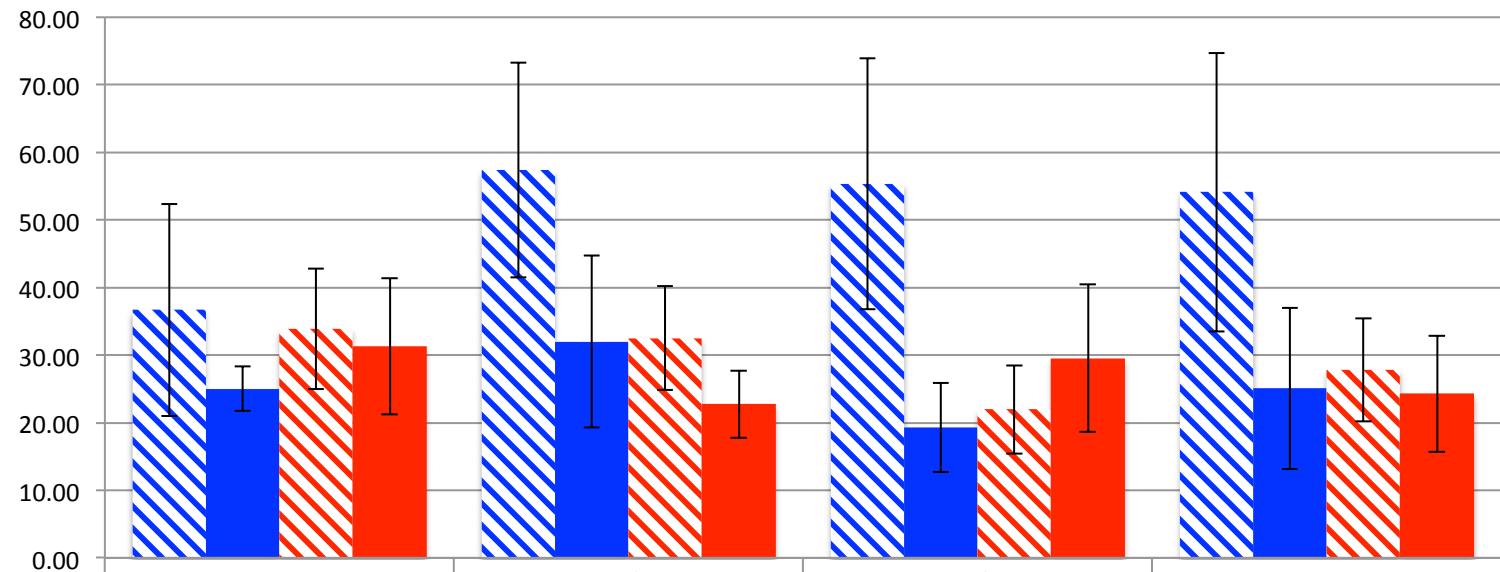
Non-Cooperative SS Alerts



- There was no significant effect of Display on Alert Duration Time for Non-Cooperative SS alerts, $p > .05$
- Pilots had an average duration of **30.25 seconds** for all Non-Cooperative SS alerts



Alert Duration Time



Cooperative/Predictive	36.67
Cooperative/Non-Predictive	25.00
Non-Cooperative/Predictive	33.87
Non-Cooperative/Non-Predictive	31.29

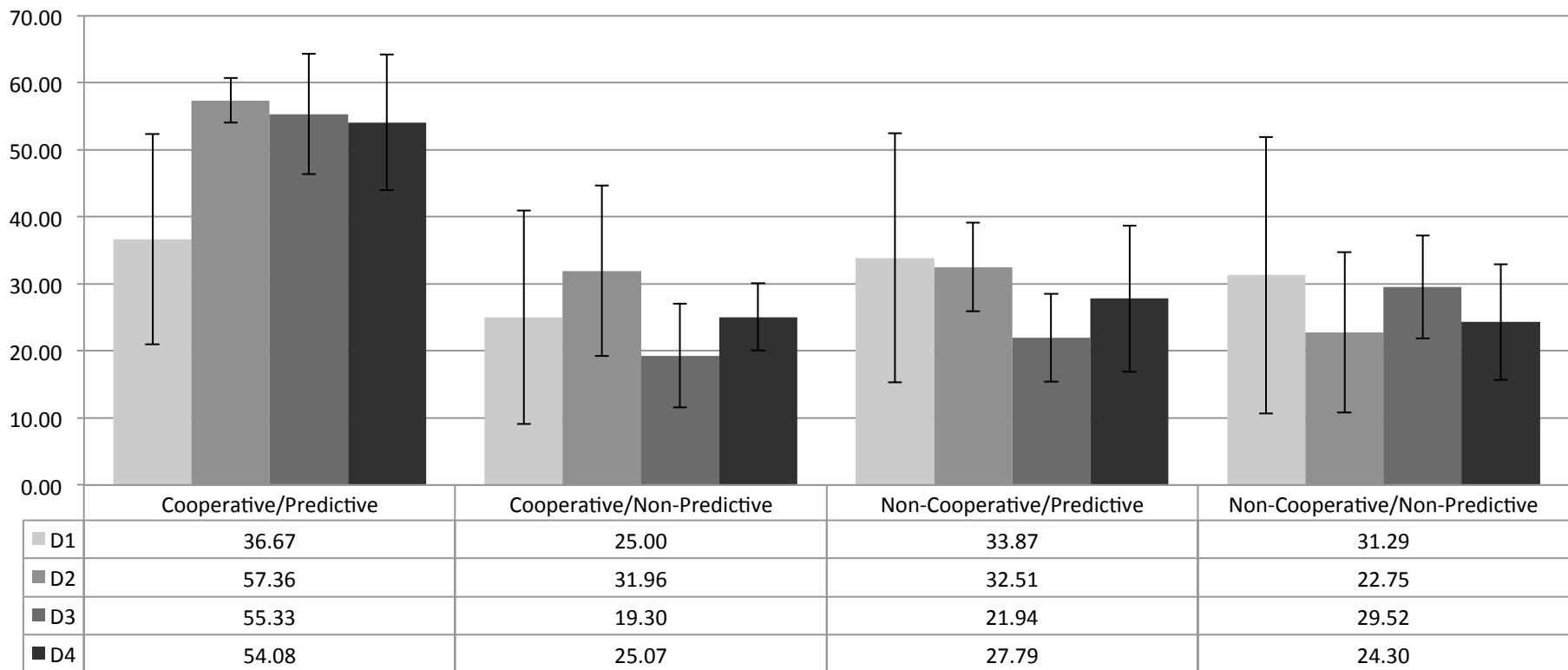
D1	57.36
D2	31.96
D3	19.30
D4	25.07

D1	55.33
D2	32.51
D3	21.94
D4	27.79

D1	54.08
D2	31.29
D3	29.52
D4	24.30



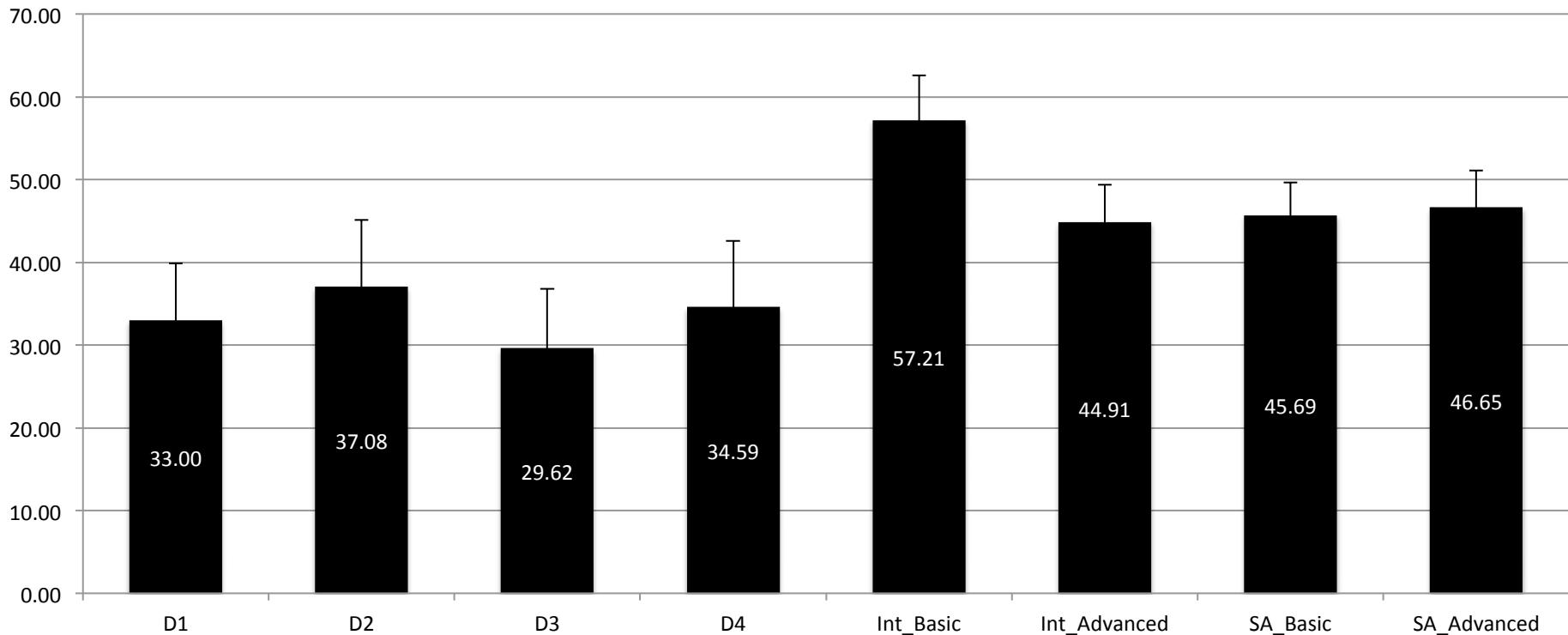
Alert Duration Time





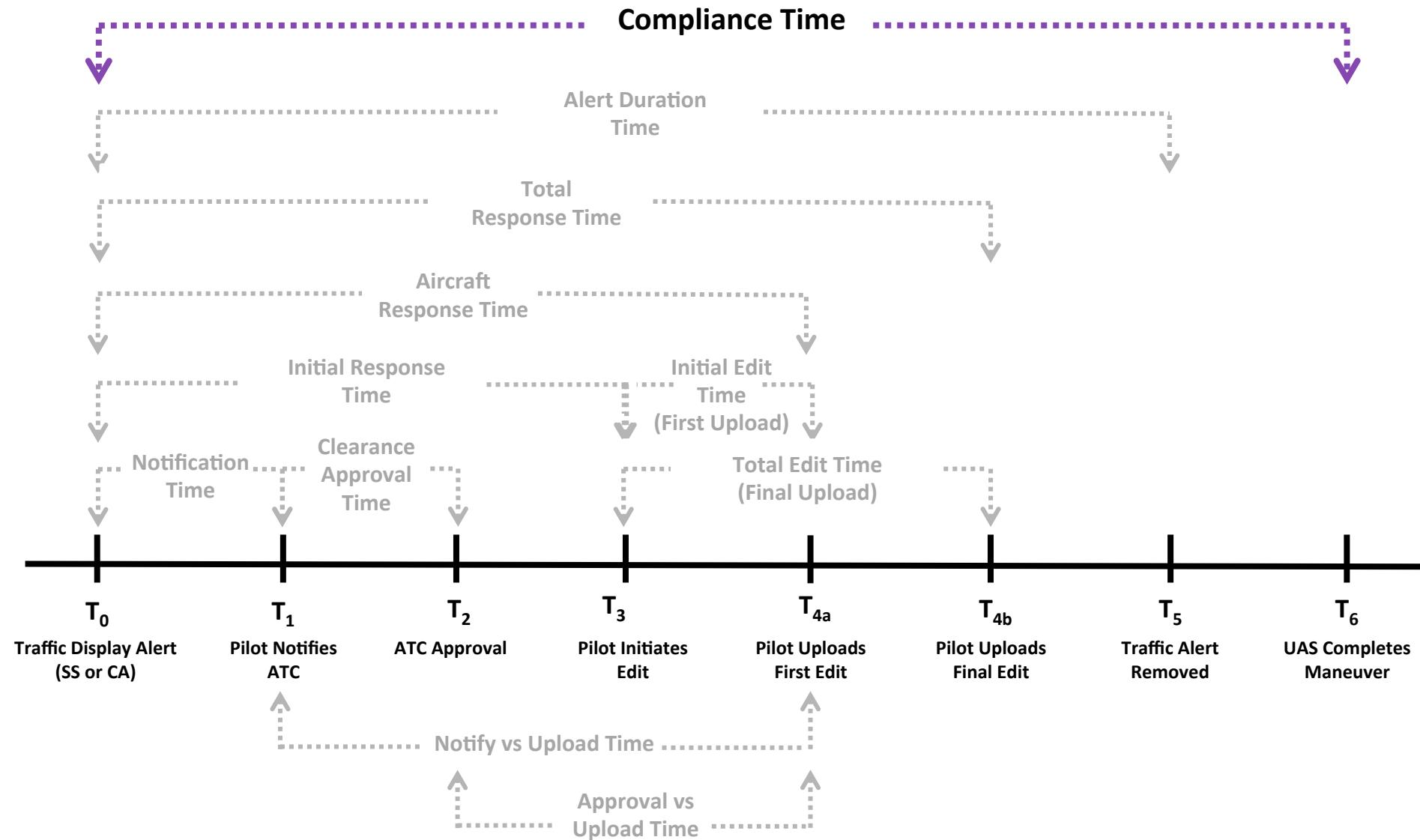
Alert Duration Time

IHTML and PT4 Display Comparison



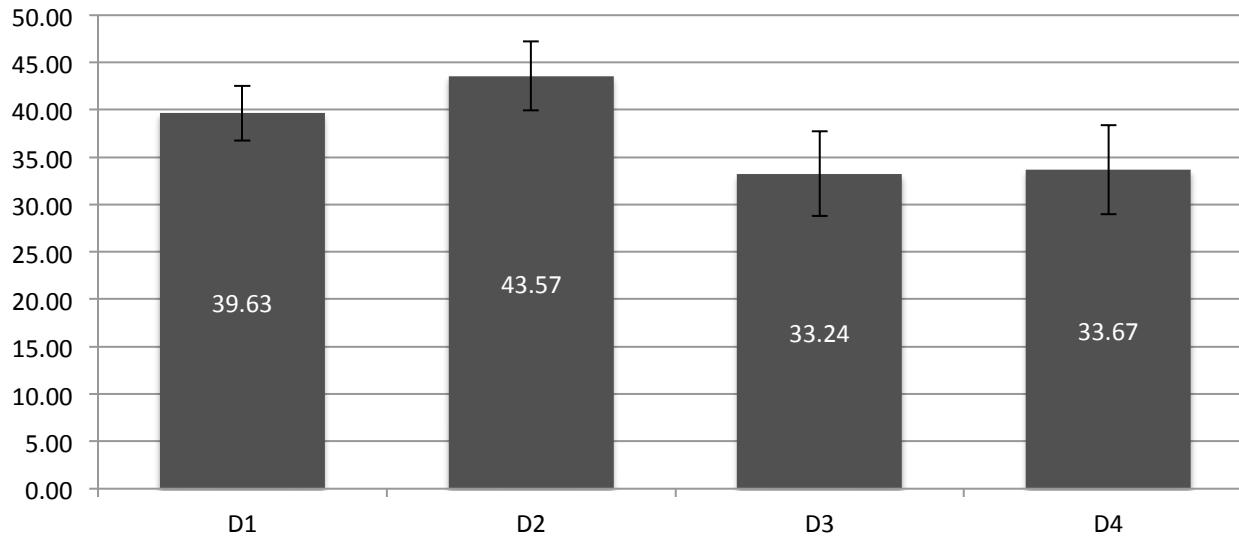


Stages of Pilot DAA Task





Compliance Time

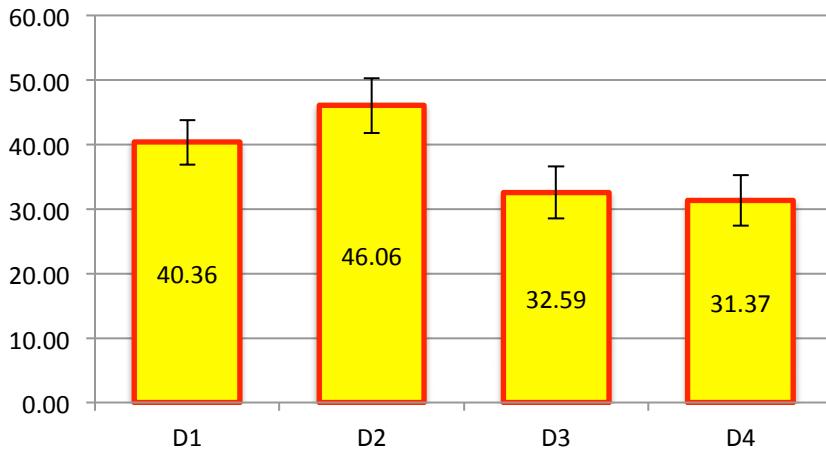


- There was a significant effect of Display on Compliance Time for all SS alerts, $p < .05$
 - No differences between displays were significant
- Pilots took an average of **37.53 seconds** to fully complete a maneuver in response to SS alerts (alert to end of aircraft maneuver)

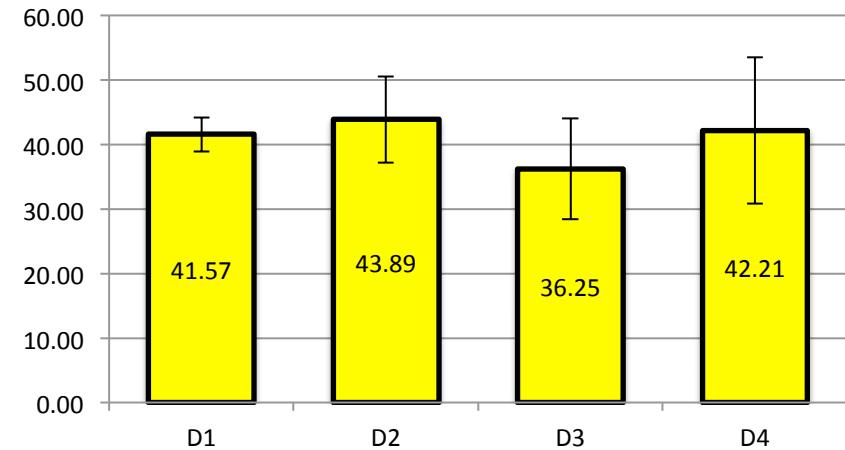


Compliance Time

Predictive SS Alerts



Non-Predictive SS Alerts



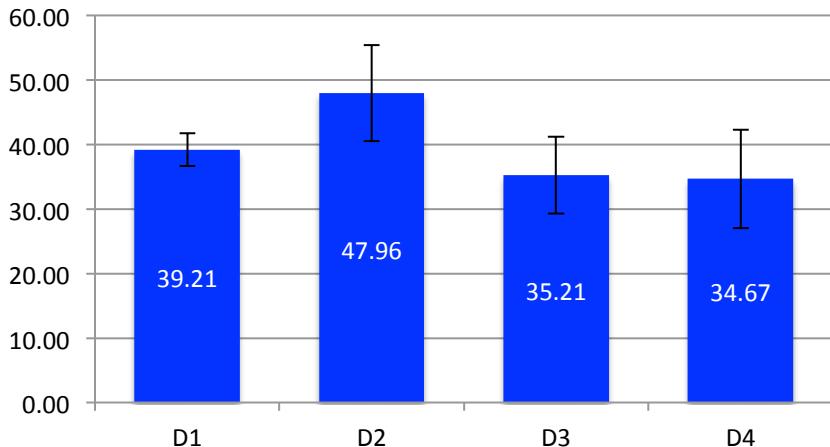
- There was a significant effect of Display on Compliance Time for all SS alerts, $p < .05$
 - No differences between displays were significant
- Pilots took an average **of 37.60 seconds** to fully complete a maneuver in response to Predictive SS alerts (alert to end of aircraft maneuver)

- There was no significant effect of Display on Compliance Time for Non-Predictive SS alerts, $p > .05$
- Pilots took an average **of 41.03 seconds** to fully complete a maneuver in response to Non-Predictive SS alerts (alert to end of aircraft maneuver)



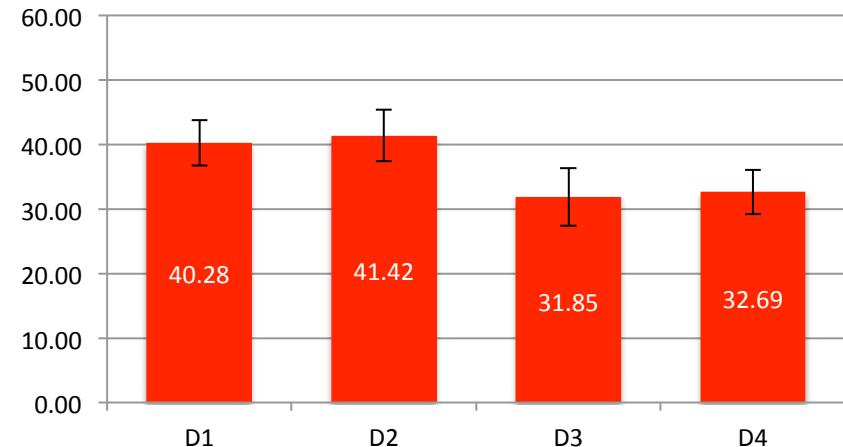
Compliance Time

Cooperative SS Alerts



- There was no significant effect of Display on Compliance Time for Cooperative SS alerts, $p > .05$
- Pilots took an average **of 39.27 seconds** to fully complete a maneuver in response to Cooperative SS alerts (alert to end of aircraft maneuver)

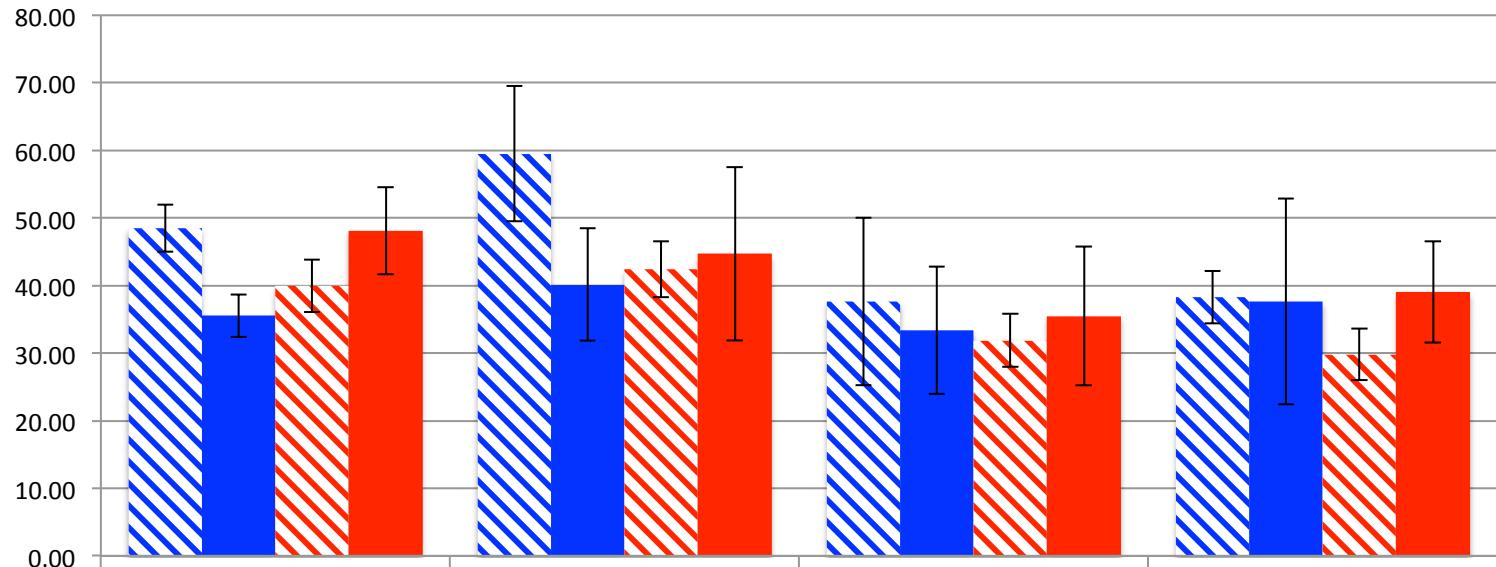
Non-Cooperative SS Alerts



- There was no significant effect of Display on Compliance Times for Non-Cooperative SS alerts, $p > .05$
- Pilots took an average **of 36.56 seconds** to fully complete a maneuver in response to Non-Cooperative SS alerts (alert to end of aircraft maneuver)



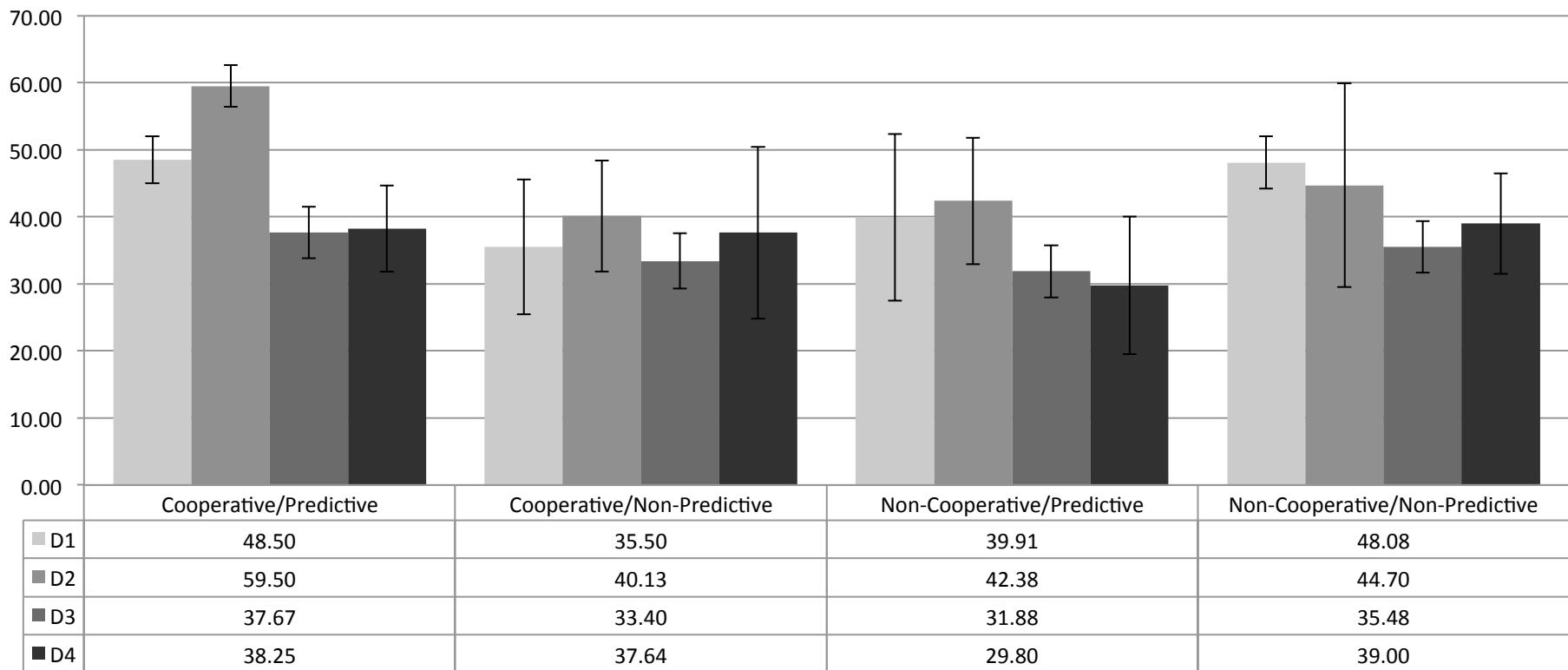
Compliance Time



Cooperative/Predictive	48.50
Cooperative/Non-Predictive	35.50
Non-Cooperative/Predictive	39.91
Non-Cooperative/Non-Predictive	48.08



Compliance Time





Compliance Time

IHTIL and PT4 Display Comparison

